# Urban Sustainability and Public Health: Throwing the Bath Water Out and Not the Baby

Dale A. Quattrochi

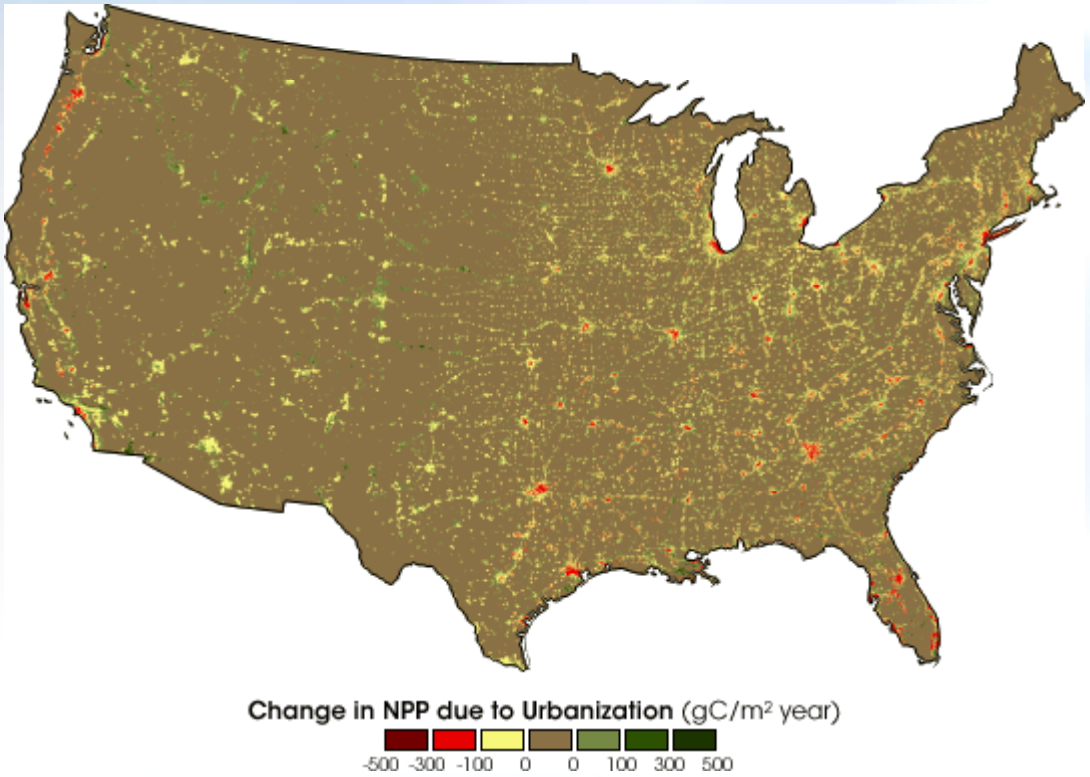
NASA

Earth Science Office

Marshall Space Flight Center

Huntsville, Alabama

# U.S. Urbanization



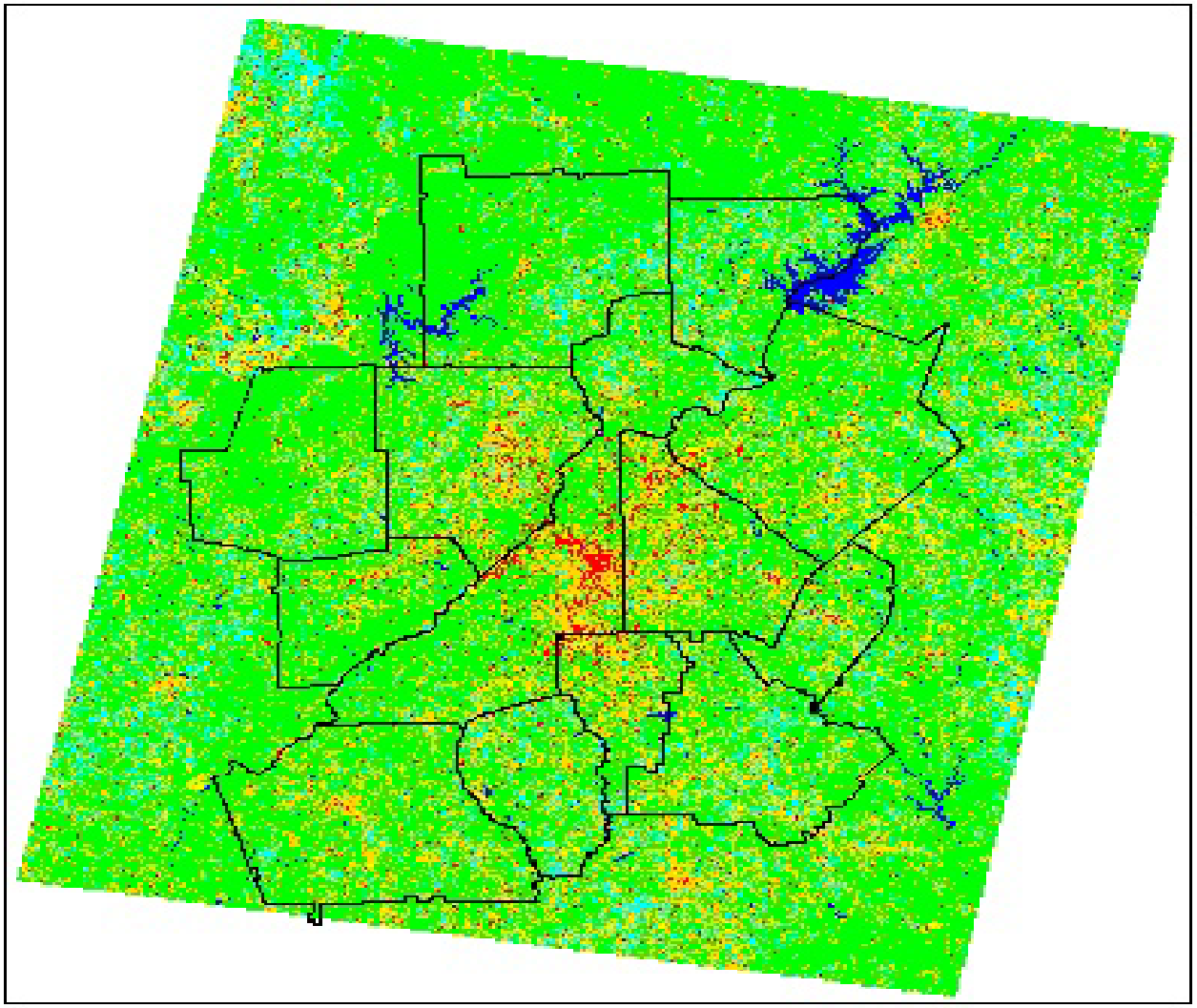

•Total Impervious Surface Area of Continental U.S. is 112,610 $km^2$
(Slightly smaller than the state of Ohio)

Source: EOS, June 2004

# Urbanization Impacts

- Increases Surface Runoff
- Reduces Carbon Sequestration
- Alters Energy Balance

# LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1973



LEGEND

- High-Density Urban Use
- Low-Density Residential
- Cultivated / Exposed Land
- Cropland and Grassland
- Forest Land
- Water

N
W E
S

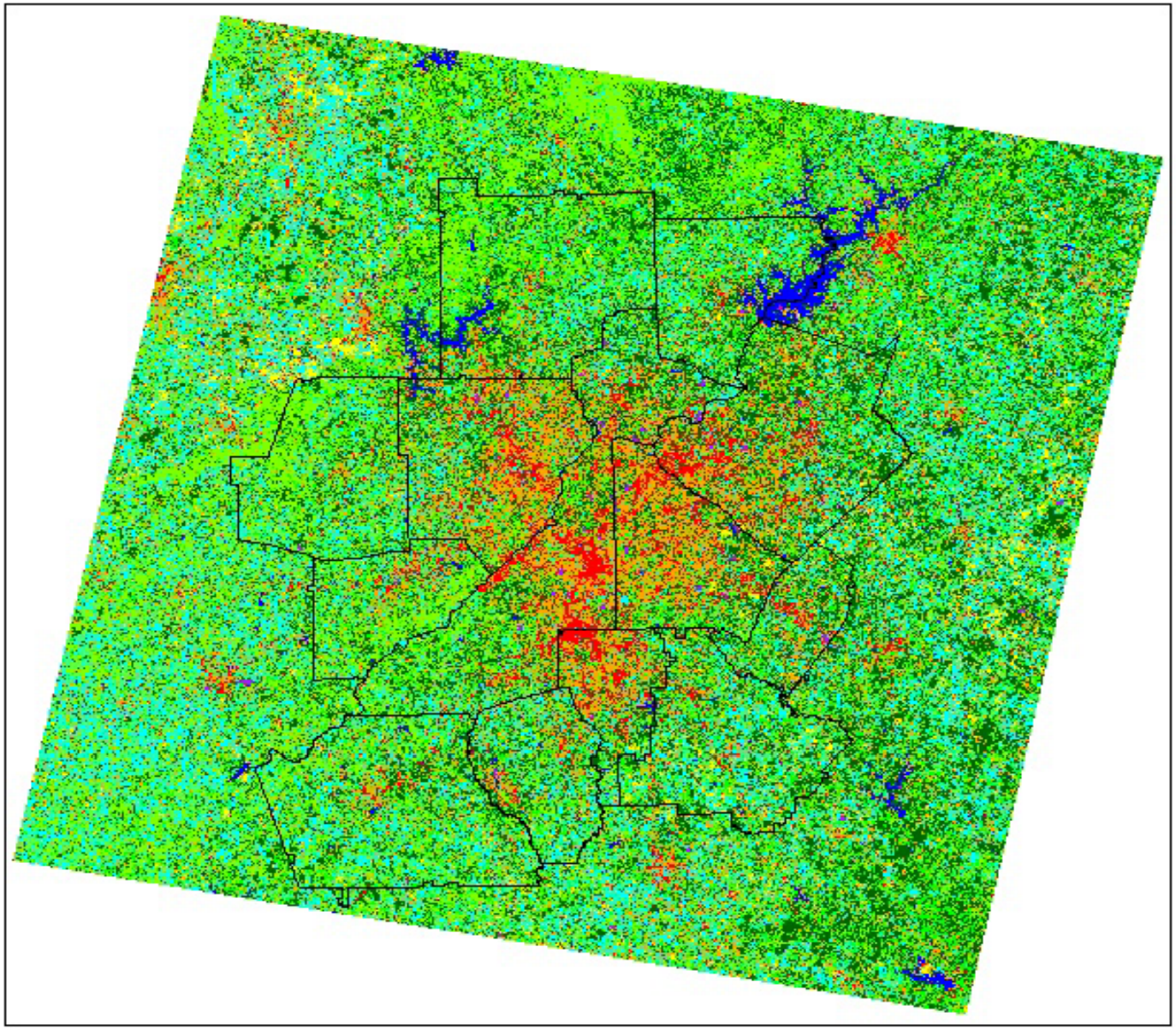
Based on Landsat MSS
Image Dated April 13, 1973

Atlanta Regional Commission
Boundary Shown

Kilometers

30 0 30 60 90

# LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1987




LEGEND

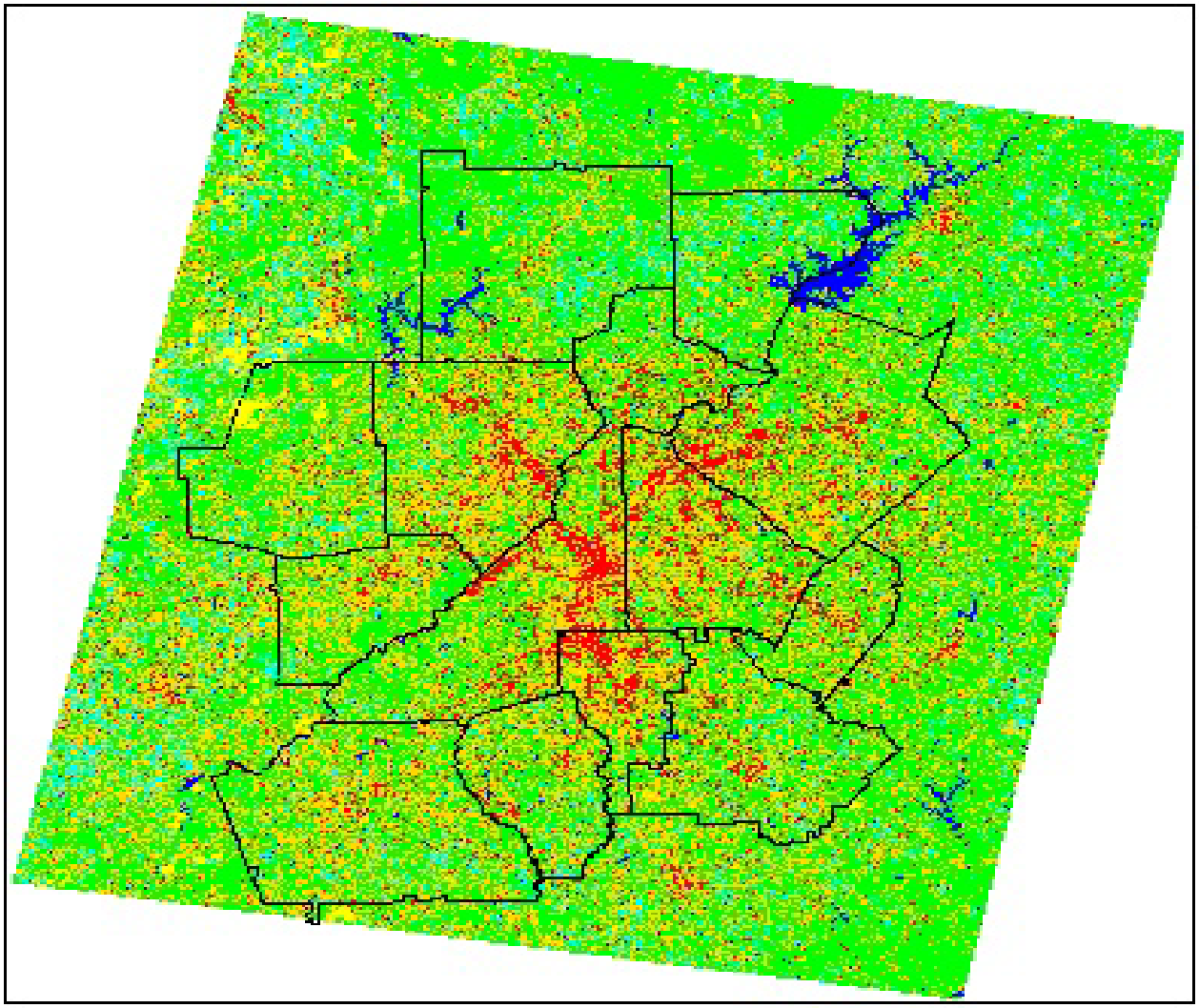
- High-Density Urban Use
- Low-Density Residential
- Cultivated / Exposed Land
- Cropland and Grassland
- Golf Courses and Parks
- Evergreen Forest
- Mixed Forest Land
- Deciduous Forest
- Water

N
W E
S

Based on Landsat TM Images
Dated June 29 , 1987

Atlanta Regional Commission
Boundary Shown

# LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1992



LEGEND

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- Water

N
W E
S

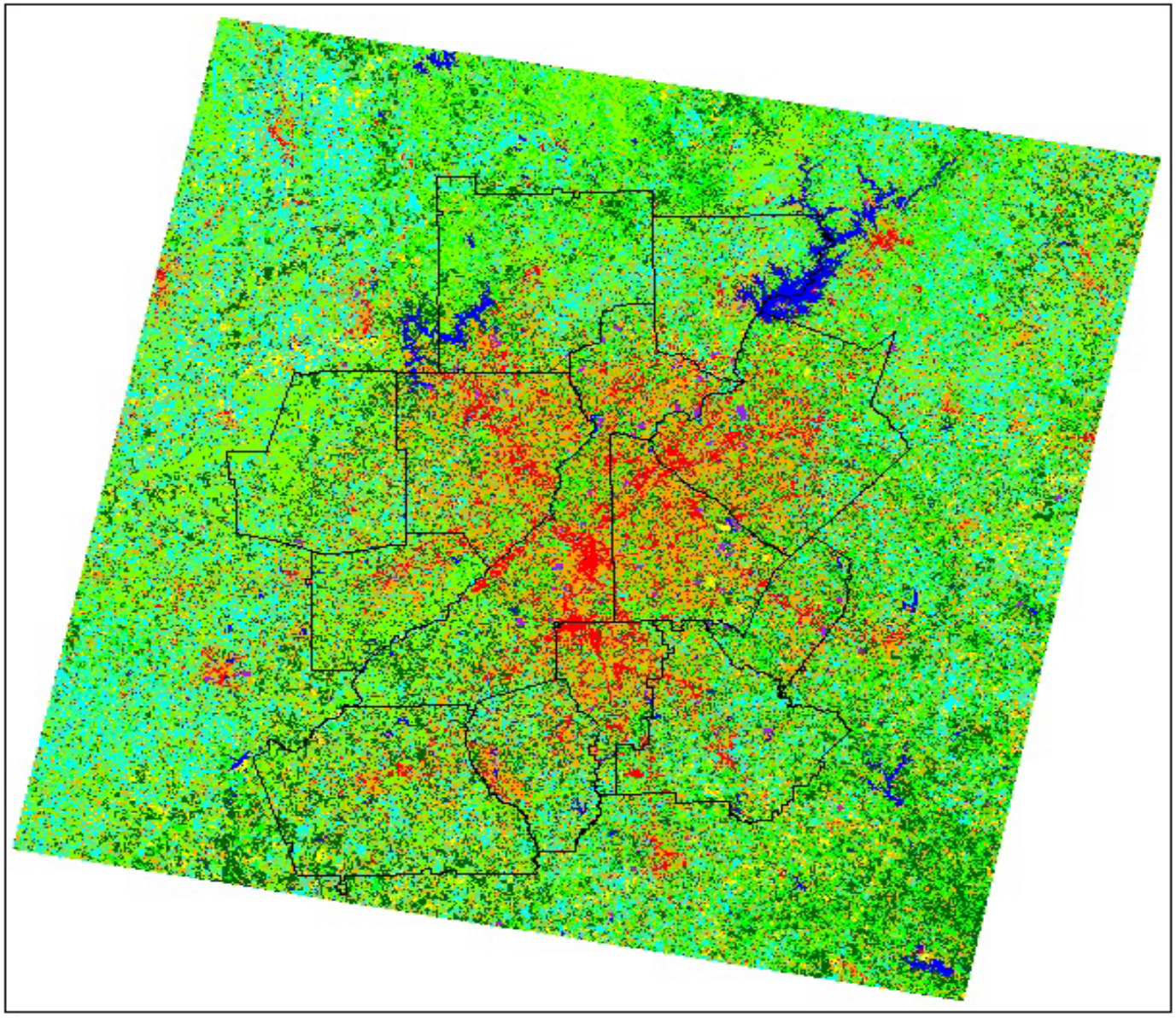
Based on Landsat MSS
Image Dated April 23, 1992

Atlanta Regional Commission
Boundary Shown

Kilometers

30 0 30 60 90

# LAND USE MAP OF THE ATLANTA, GEORGIA METROPOLITAN AREA , 1997-1998




LEGEND

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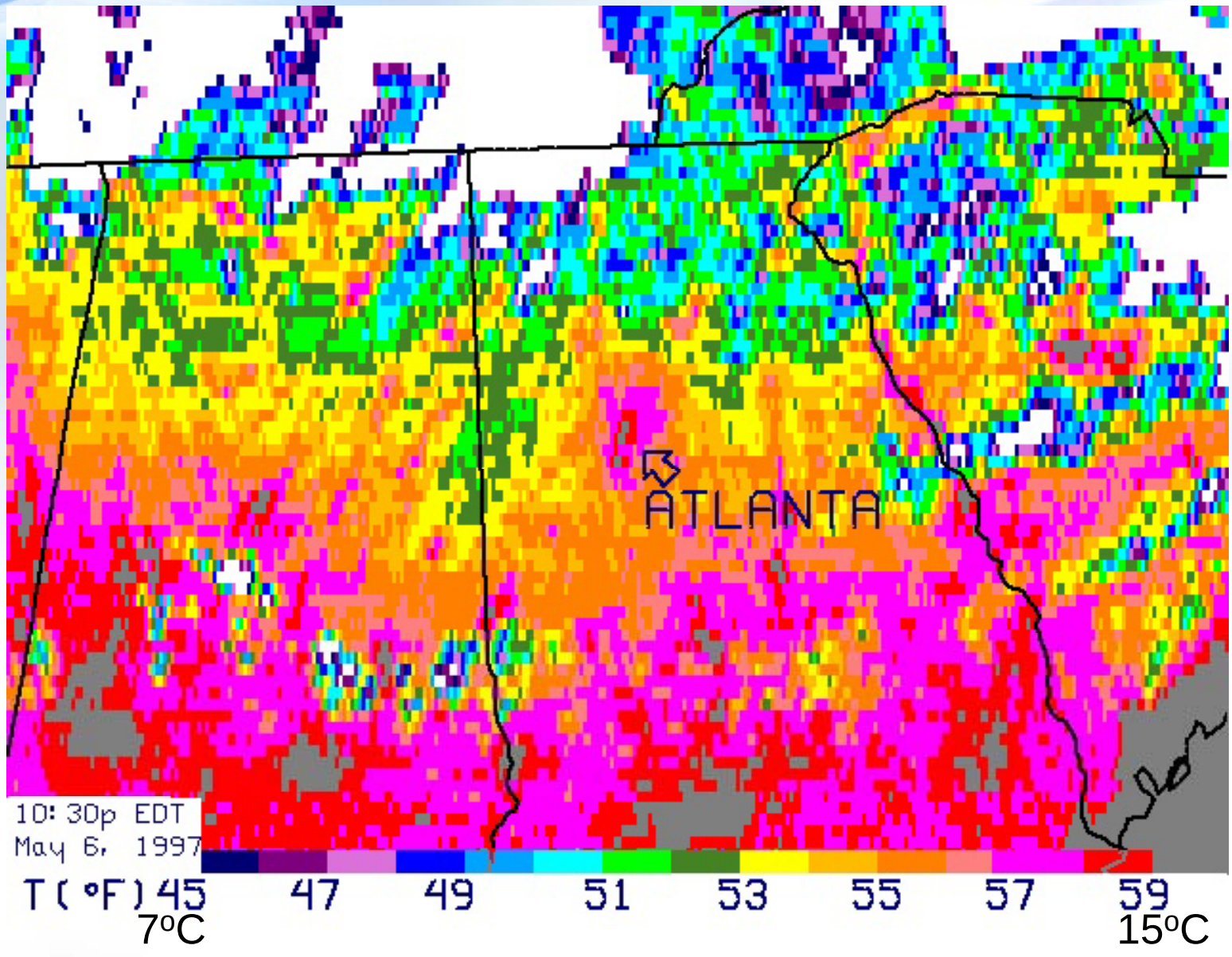
- Cultivated / Exposed Land
- Cropland and Grassland
- Golf Courses and Parks
- Evergreen Forest
- Mixed Forest Land
- Deciduous Forest
- Water

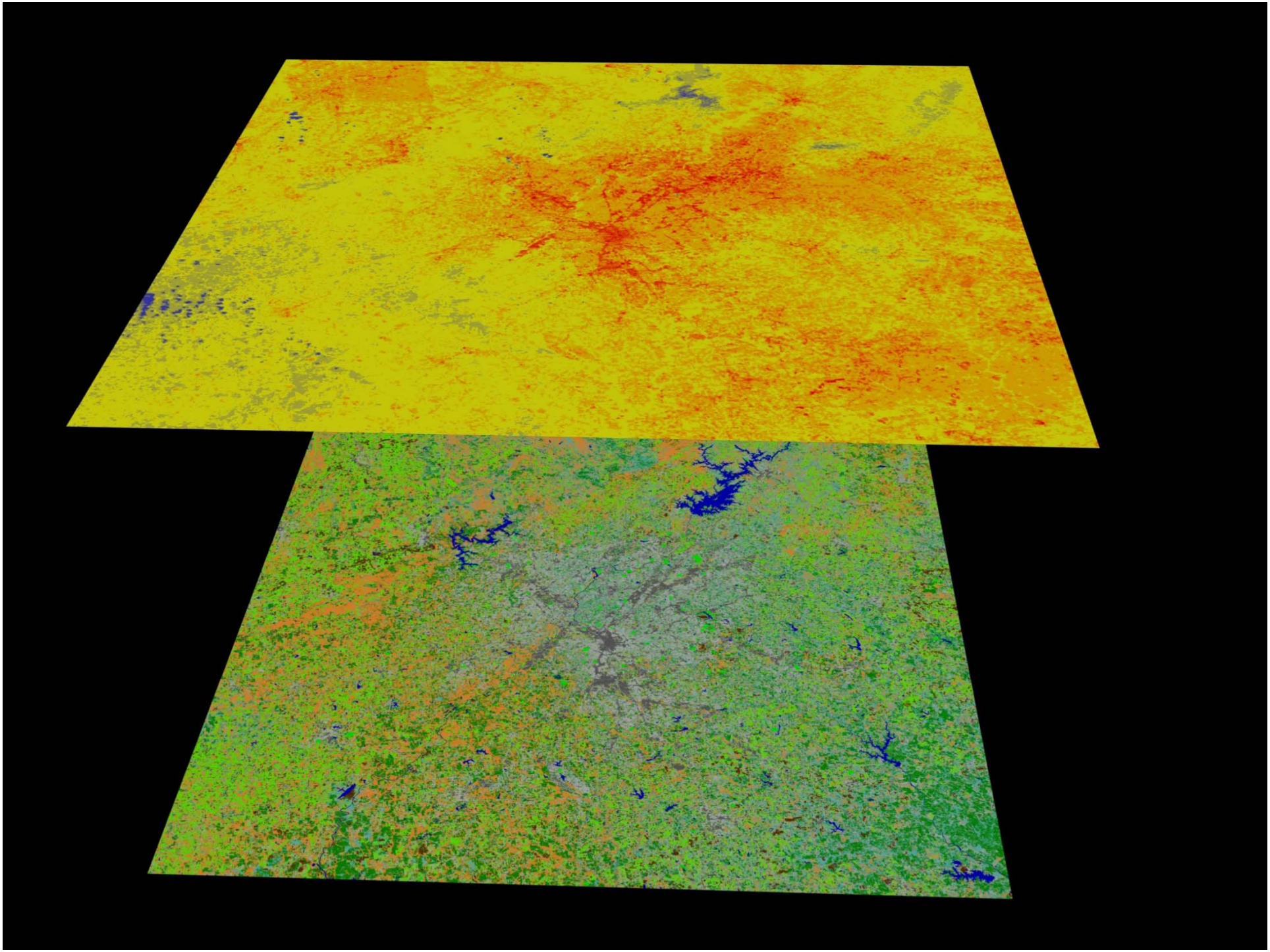
N
W E
S

Based on Landsat TM Images Dated July 10, 1997 and Jan. 2, 1998

Atlanta Regional Commission Boundary Shown

# NAS Sustainable Urban Systems Forum





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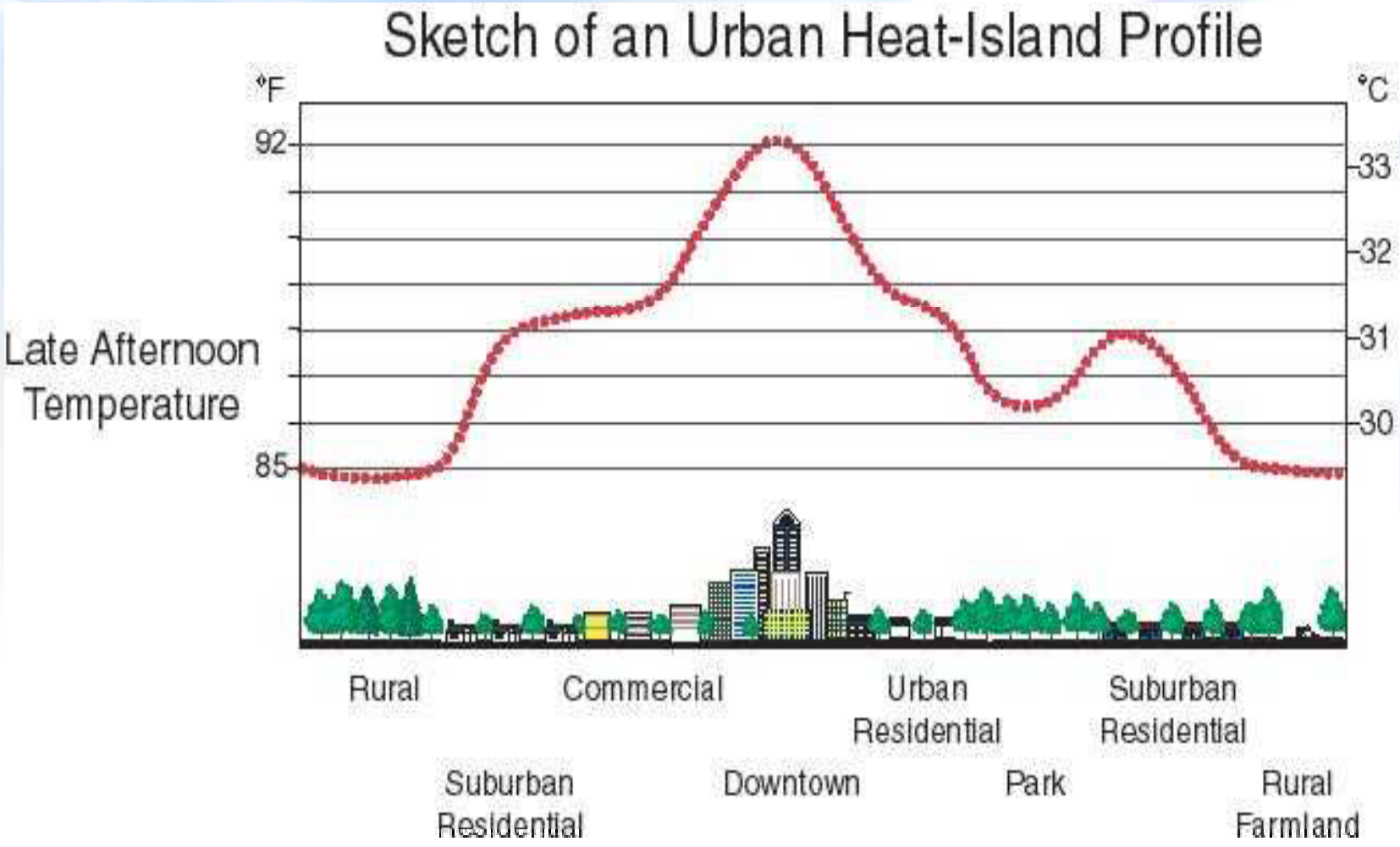


# NAS Sustainable Urban Systems Forum

Mission to Planet Earth
National Aeronautics and Space Administration

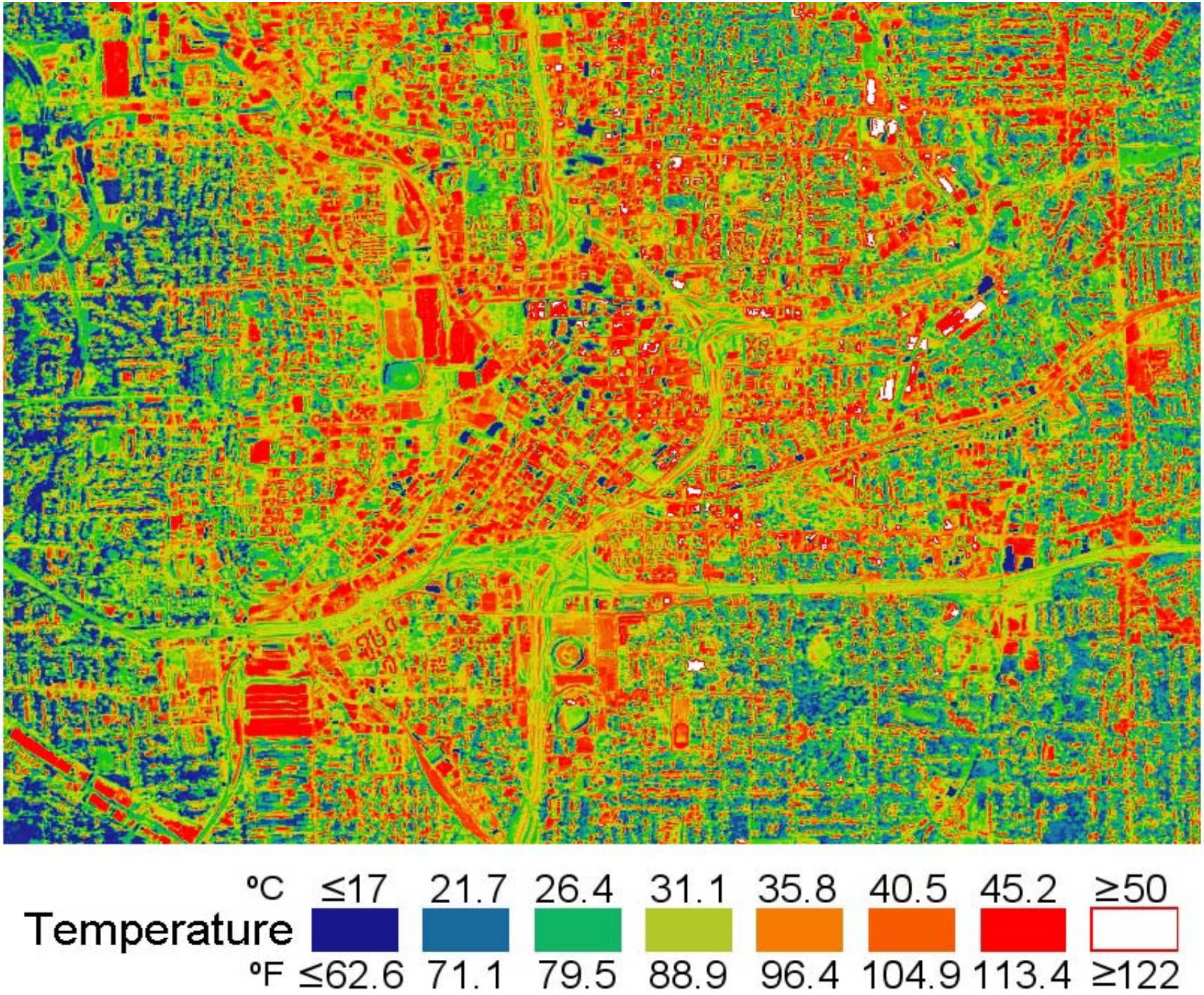
## Urban Remote Sensing and Air Quality Models

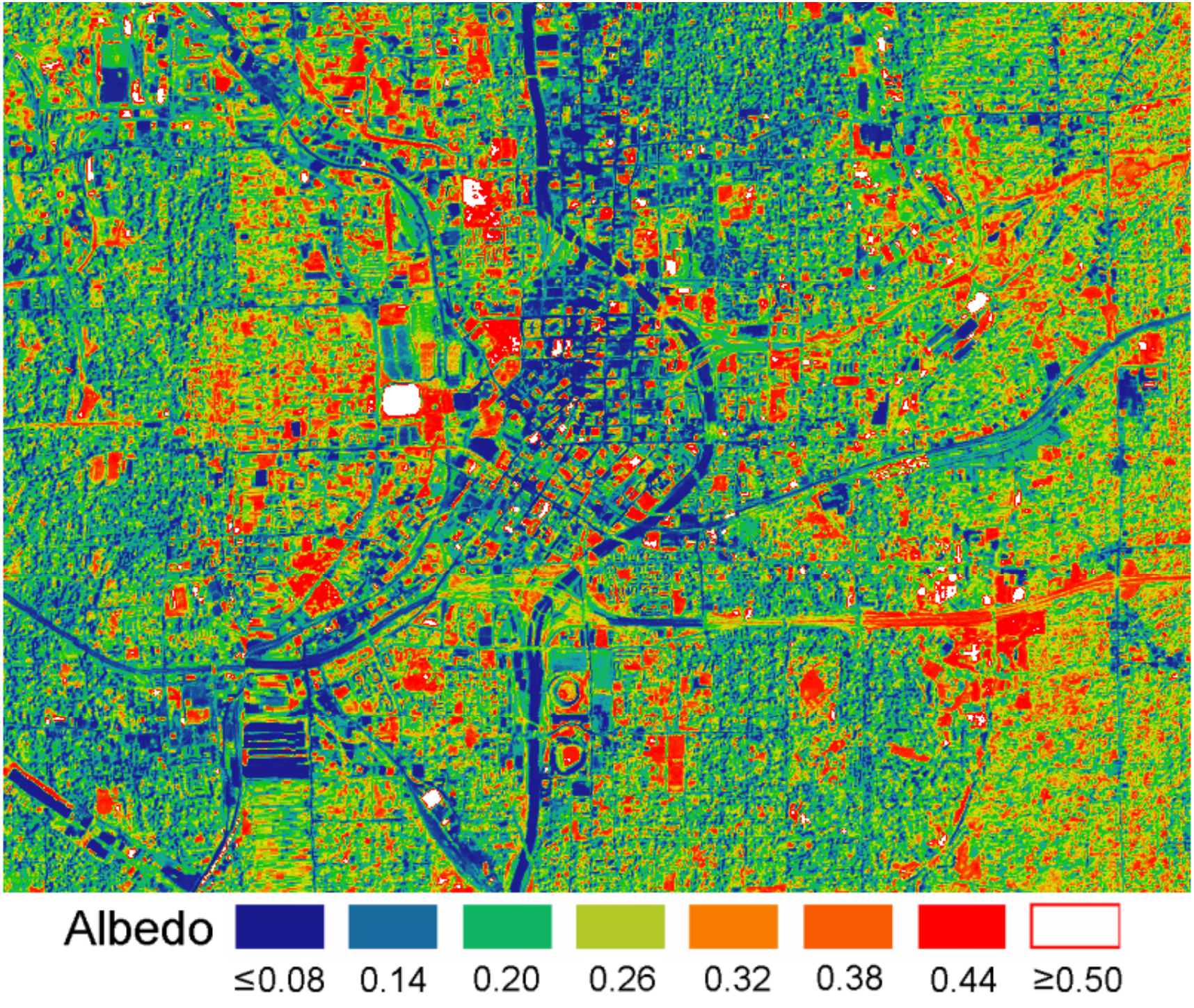
Volatile Organic Compounds
+ Nitrogen Oxides
+ Sunlight
→ Ozone

- Air pollution remains a National issue.
- Temperature increases the ozone levels.
- Urban heat island has major effect on temperature and height of mixing layer.
- Measurement program is defining land use patterns and relationship to heat production.
- Remote sensing data are being used to improve air quality modeling.

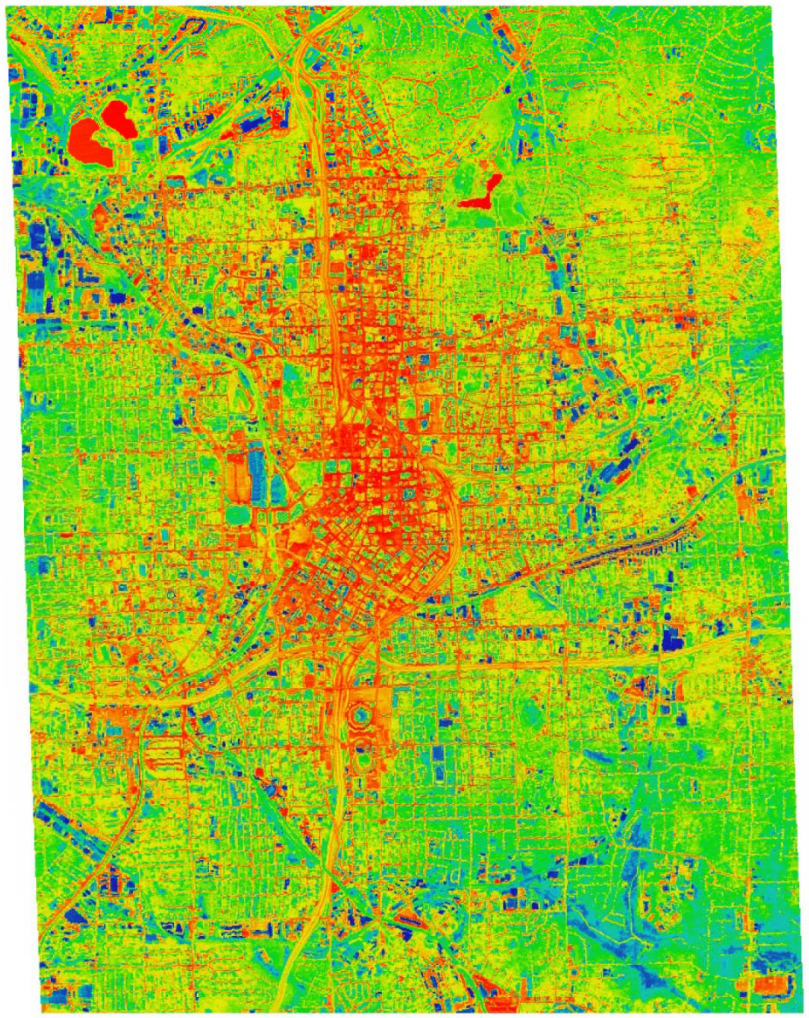
5-30754

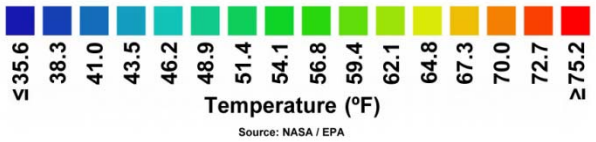
# NAS Sustainable Urban Systems Forum

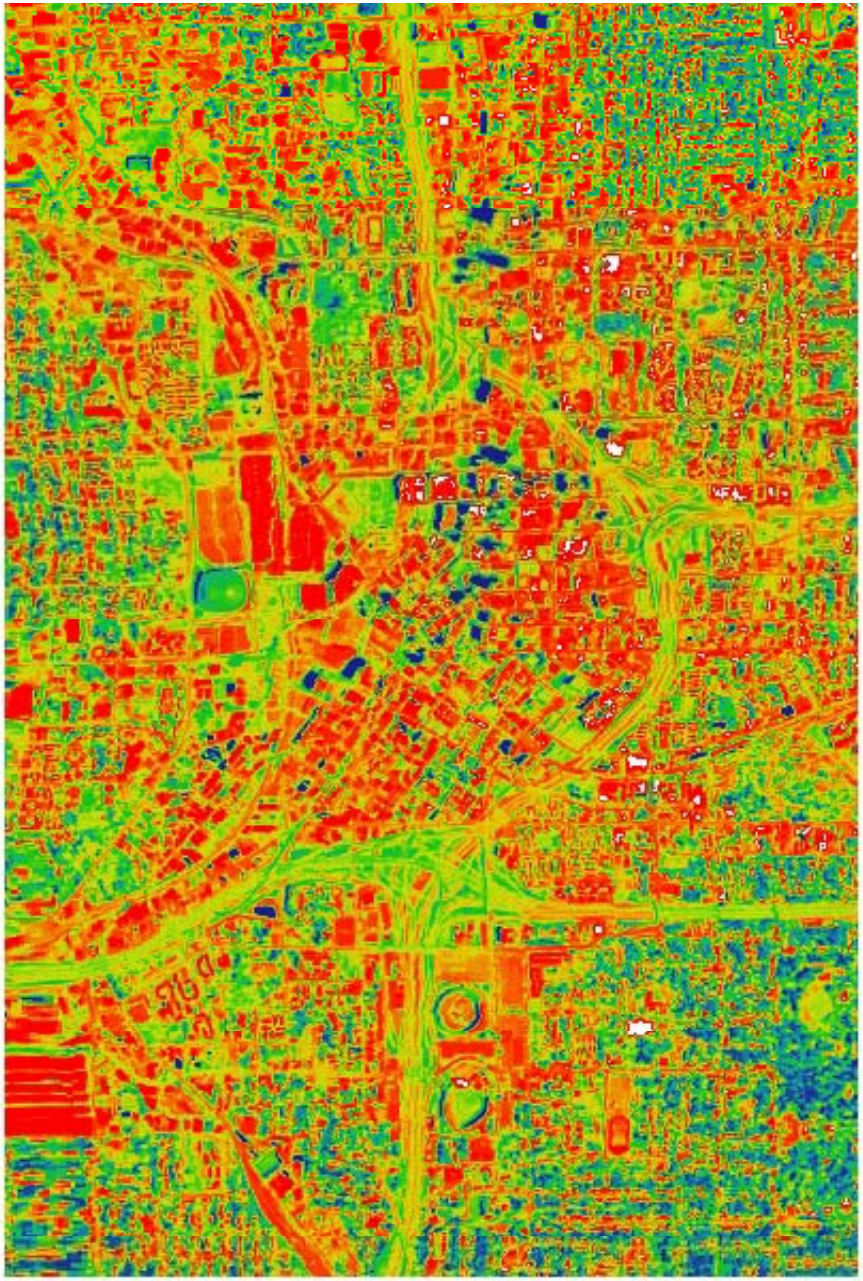

°C ≤17 21.7 26.4 31.1 35.8 40.5 45.2 ≥50
Temperature
°F ≤62.6 71.1 79.5 88.9 96.4 104.9 113.4 ≥122


Albedo
≤0.08
0.14
0.20
0.26
0.32
0.38
0.44
≥0.50

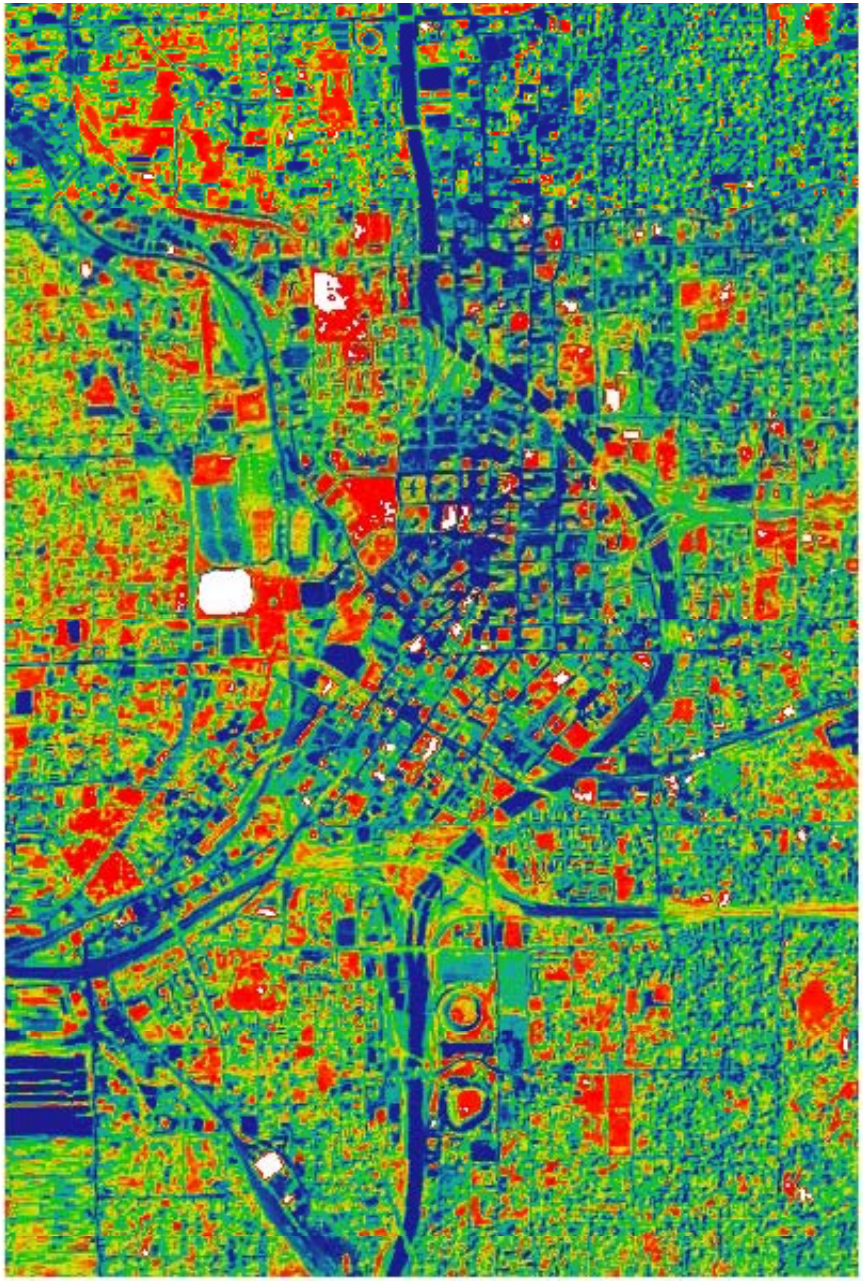
# Atlanta
# Central Business District
# Night Data – May 1997







Temperature



Albedo

Atlanta. GA - May 1997

# Impervious Surfaces

# NAS Sustainable Urban Systems Forum

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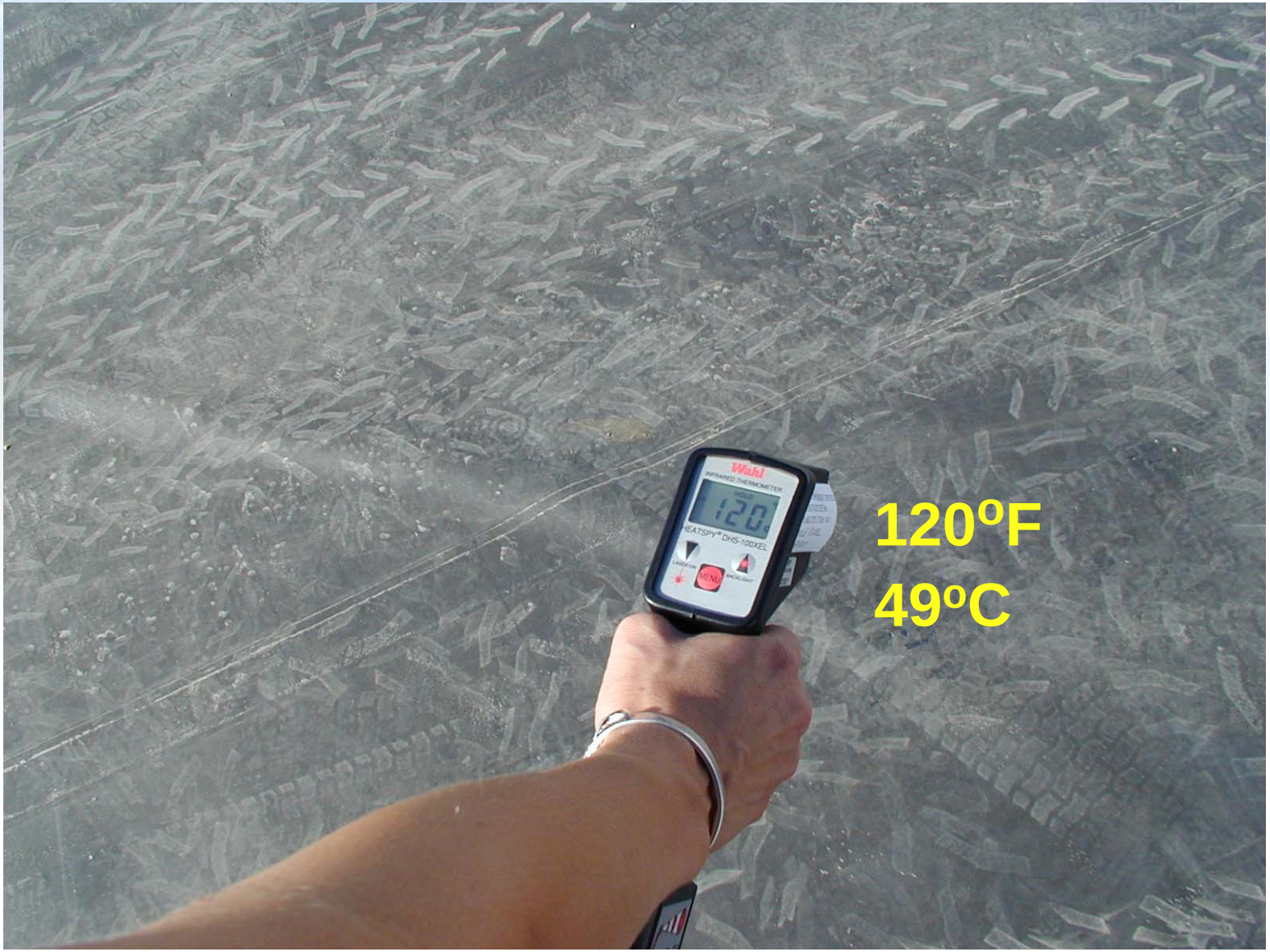

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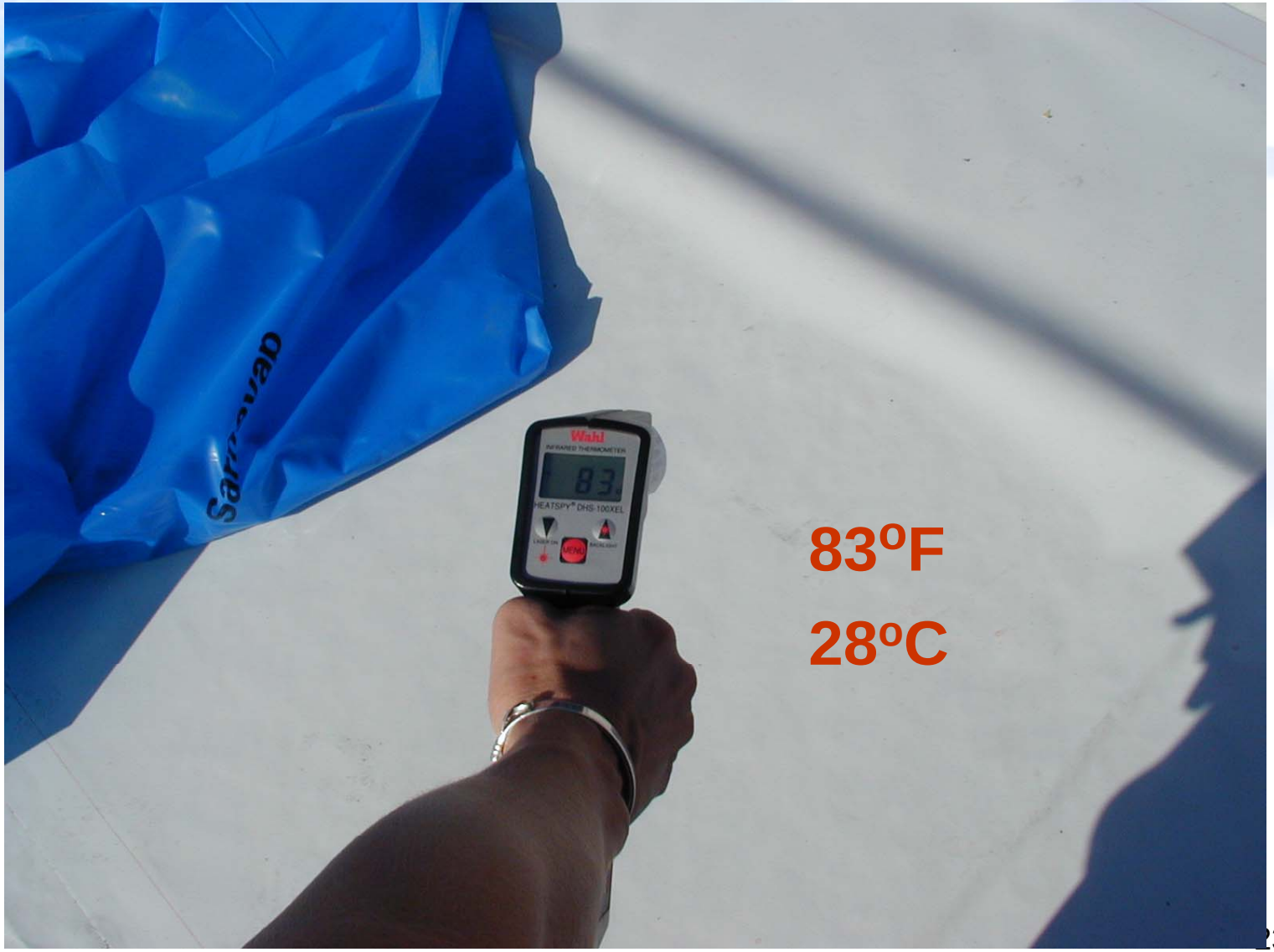


## Mitigation Measures

- **Green roofs**

## Mitigation Measures

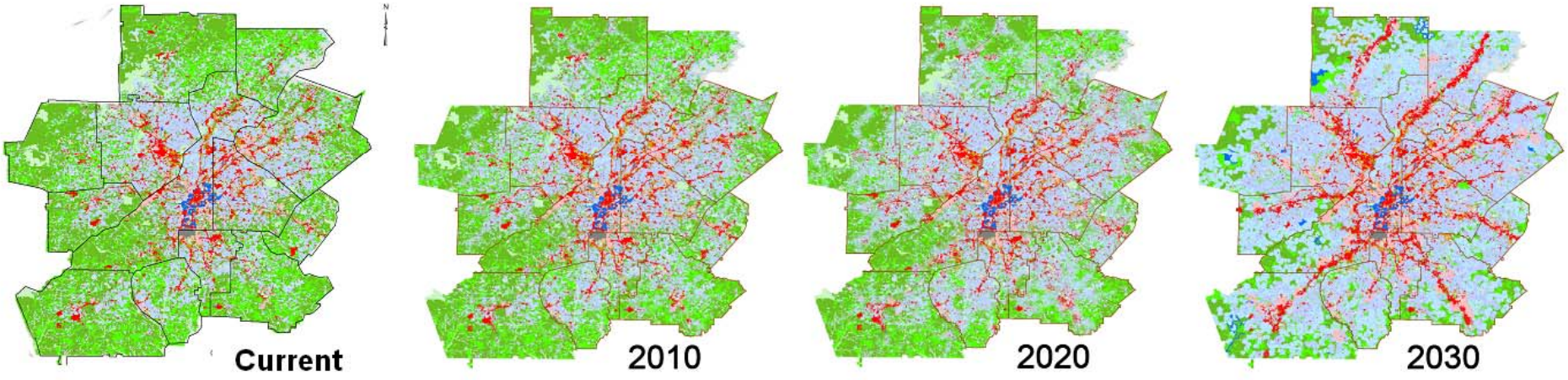
- **Less impervious land cover**

## Mitigation Measures

- **Shade trees**

# Mitigation Strategies

# Spatial Growth Modeling Results

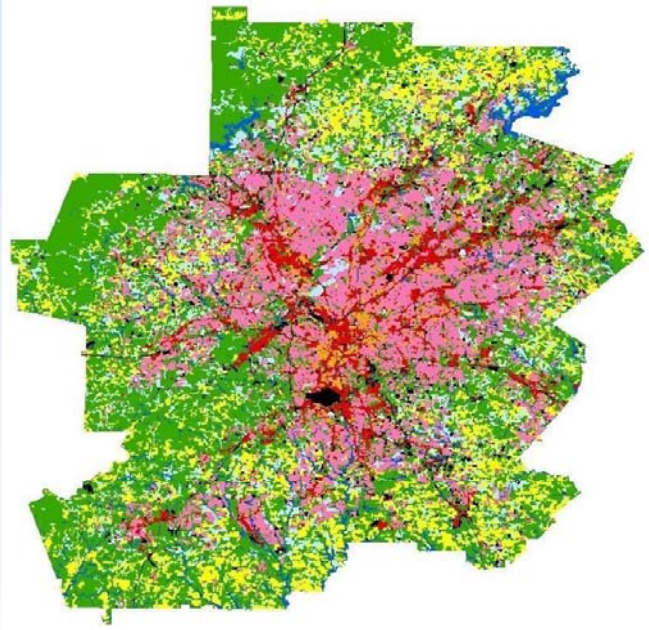



## Legend

- AG_CONFINED
- AG_CROPS
- AG_ORCHARD
- COMMERCIAL
- FOREST
- IND/COM
- INDUSTRIAL
- INST_EXTENSIVE
- INST_INTENSIVE
- LTD_ACCESS
- PARKS
- RESERVOIRS
- RES_HIGH
- RES_LOW
- RES_MED
- RES_MOBILE
- RES_MULTI
- RIVERS
- TCU
- TRANSITIONAL
- URBAN_OTHER

# Current and Projected 2030 Land Use
# 13-county Atlanta Metro Area

## Current (1999)



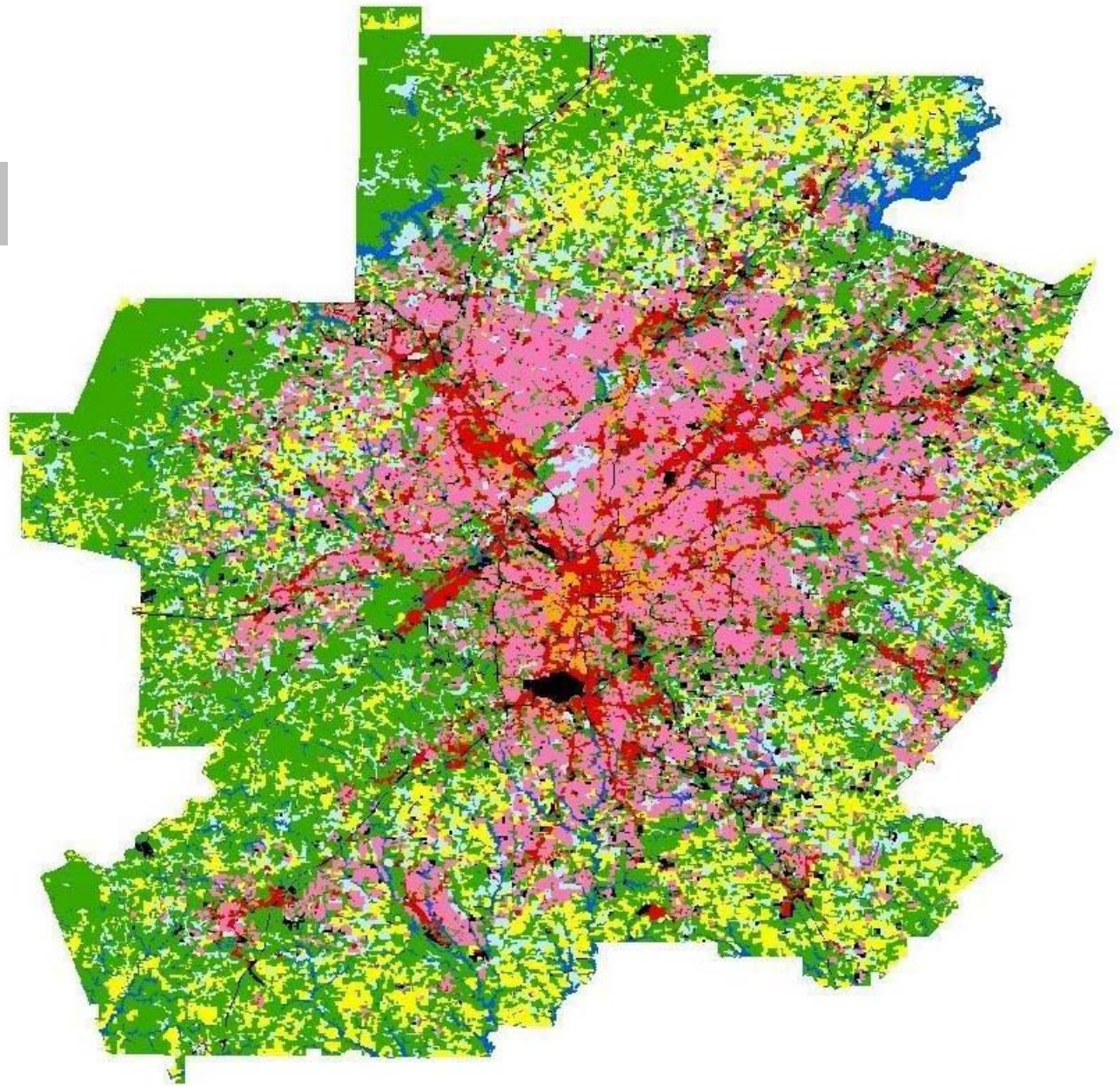
- Low Density Residential
- Med. Density Residential
- High Density Residential
- Commercial/Services
- Institutional
- TCU
- Industrial/Commercial
- Water
- Crops/Pasture
- Row Crops
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Woody Wetlands
- Quarries/Mines/Gravel Pits
- Transitional

## Projected (2030)

**The Spatial Growth Model (SGM) was used to project land use/land cover for the area to 2030.**
**Inputs to the model are current land use and current and projected population, employment, and road networks.**
**Current land use/land cover is defined by the LandPro99 data set created by the Atlanta Regional Commission (ARC).**

# Atlanta Urban Heat Island and Air Quality Modeling Study

## Land Use in 1999



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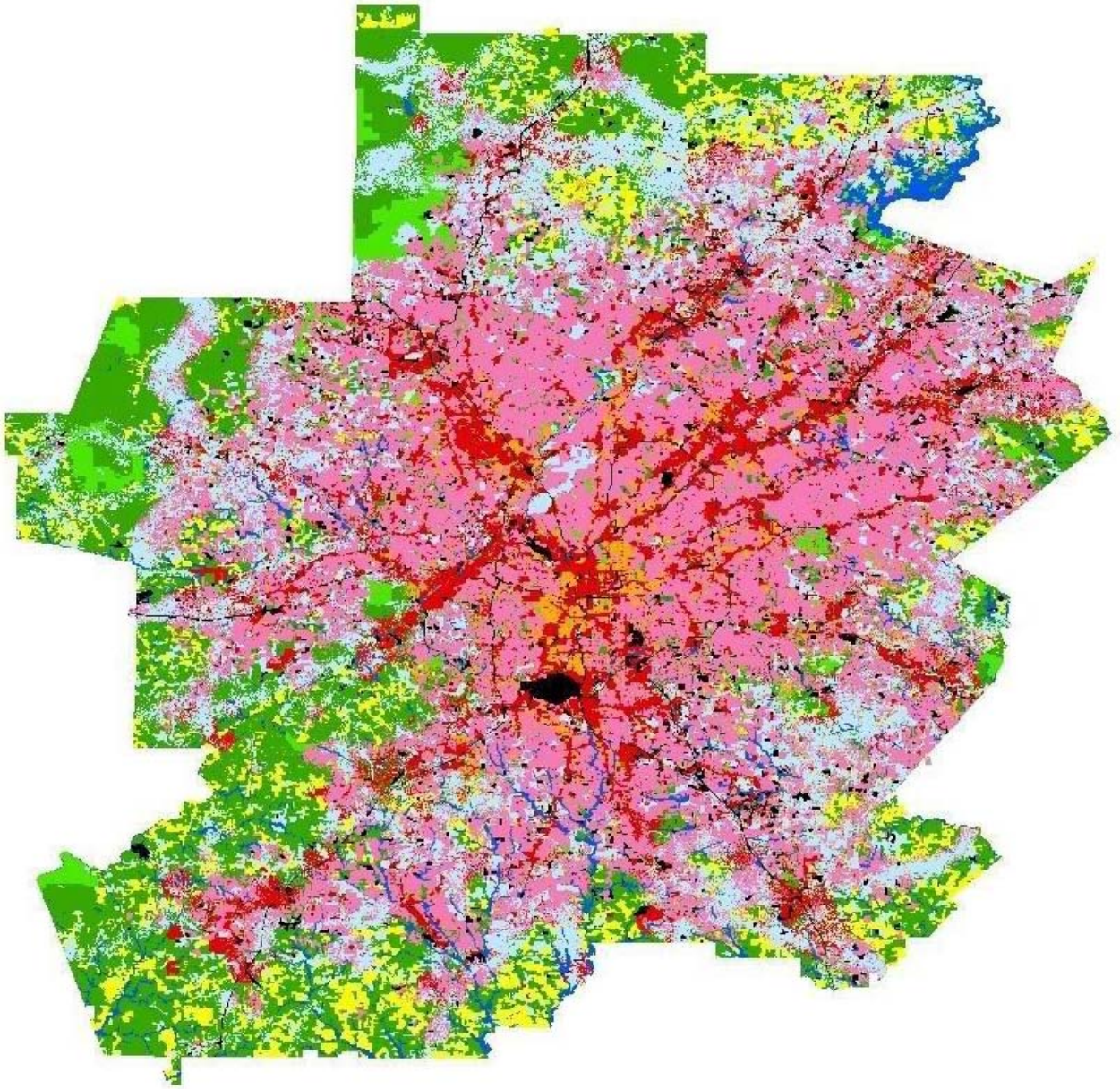
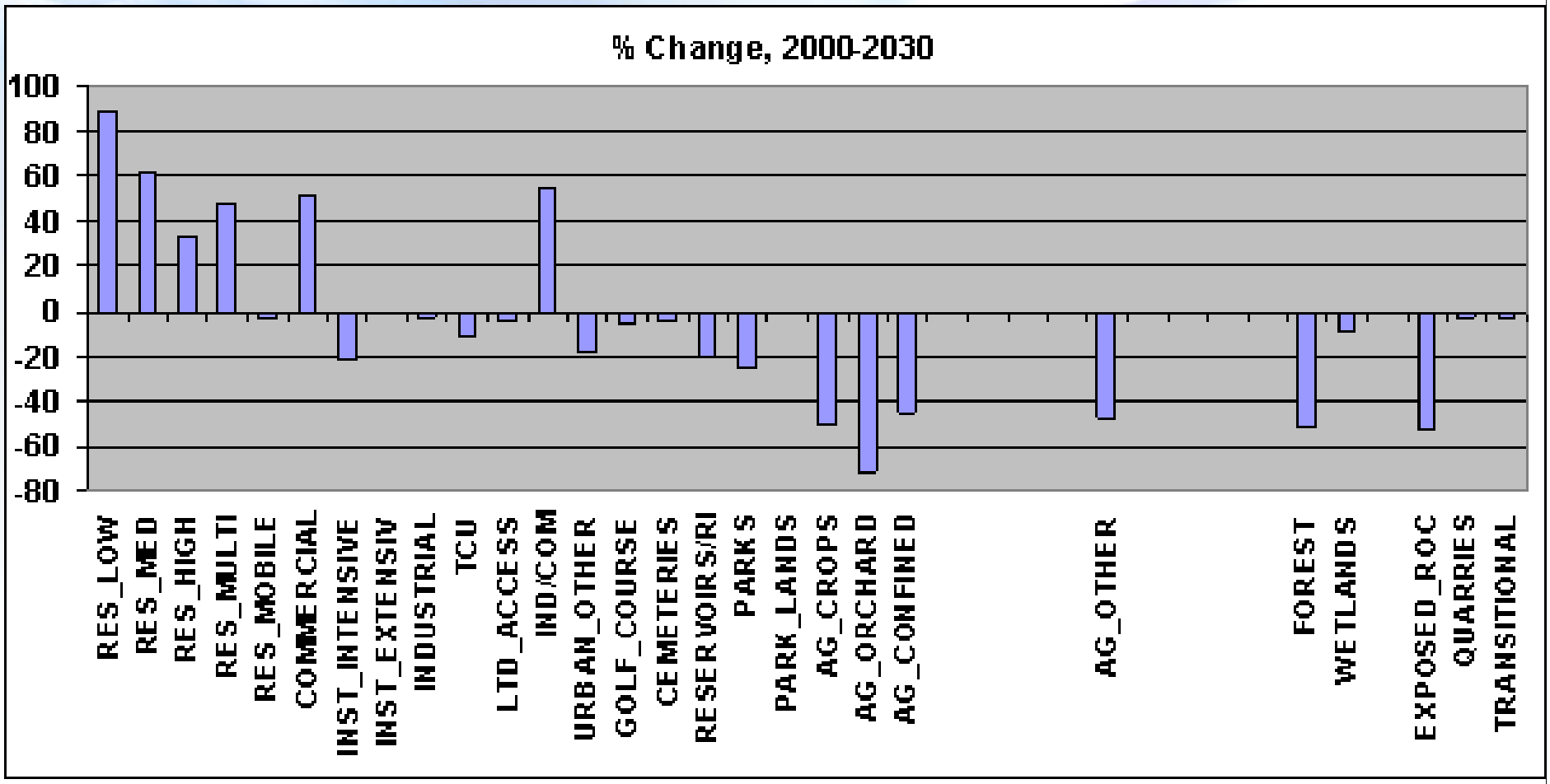
# Atlanta Urban Heat Island and Air Quality Modeling Study

## Projected Land Use in 2030



# Land Use Projections




Source: Prescott College Spatial Growth Model

# ❑Basics of Public Health

## ❑Public Health Approach

❑ *Problem*

❑Surveillance:
❑What
❑is the
❑problem?

❑Risk Factor
❑Identification:
❑What is the
❑cause?

❑Intervention
❑Evaluation:
❑What
❑works?

❑Implementation:
❑How do you
❑do it?

❑ *Respons e*

# ❑Public Health Surveillance

- Ongoing systematic collection, analysis, and interpretation of outcome-specific data used to plan, implement, and evaluate public health practice.

## ❑Surveillance Information Uses

- Monitor & detect changes in the magnitude & distribution of selected events
- Develop hypotheses for research
- Evaluate interventions
- Facilitate public health decision-making

# ❑HELIX-Atlanta Overview

## ❑The U.S. Center for Disease Control and Prevention's (CDC) National Environmental Public Health Tracking (EPHT) Program was initiated in 2002

- Congressional funding for *development and implementation of a nationwide environmental health tracking network and capacity development in environmental health at State and local health Departments*"

# ❑Tracking = Public Health Surveillance

- Environmental public health tracking is the ongoing, systematic collection, integration, analysis, and interpretation of data about the following factors:
  - environmental hazards
  - human exposure to environmental hazards
  - health effects potentially related to exposure to environmental hazards
- Data must be disseminated to plan, implement, and evaluate environmental public health action

# Environmental Public Health Tracking

Hazard

Exposure

Health Effect

Data

Ongoing Evaluation

COLLECTION → INTEGRATION → ANALYSIS → INTERPRETATION

Tracking Network

Dissemination

Assessment • Research • Intervention • Policy

Stakeholders*

Prevention

Improved Public Health

| *Stakeholders Include | |
|---|---|
| Federal Agencies | Business and Industry |
| State and Local Agencies | Policy Makers |
| Academia | Media |
| Health Care System | Public |
| Non-Governmental Organizations | |

Ongoing Evaluation

DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION
SAFER • HEALTHIER • PEOPLE

CDC
SAFER • HEALTHIER • PEOPLE™

# ❑PUBLIC HEALTH, AIR QUALITY, AND REMOTE SENSING

❑THE INTEGRATION OF PUBLIC HEALTH SURVEILLANCE, AIR QUALITY ASSESSMENT, AND REMOTE SENSING:

❑AN ATLANTA, GEORGIA CASE STUDY

# ❑Health and Environment Linked for Information Exchange (HELIX)-Atlanta

- Provide information regarding the 5-county Metro-Atlanta Area
  - Clayton, Cobb, DeKalb, Fulton, & Gwinett
- Integrate environment & public health data into a local network that is part of a national network
- Take action to prevent & control environmentally related health effects

HELIX ATLANTA
Bridging Health & Environment

# ❑HELIX-Atlanta Overview

- **HELIX-Atlanta was developed to support current and future state and local EPHT programs to implement data linking demonstration projects which could be part of the EPHT Network.**
- **HELIX-Atlanta is a pilot linking project in Atlanta for CDC to learn about the challenges the states will encounter.**
- **NASA/MSFC and the CDC are partners in linking environmental and health data to enhance public health surveillance.**
- **The use of NASA technology creates value – added geospatial products from existing environmental data sources to facilitate public health linkages.**
- **Proving the feasibility of the approach is the main objective**

# ❑HELIX-Atlanta Challenges

- **Sharing data between agencies with different missions and mindsets**
- **Protecting confidentiality of information**
- **Ensuring high quality geocoded data**
- **Ensuring appropriate spatial and temporal resolutions of environmental data**
- **Developing sound resources and methods for conducting data linkages and data analysis**

# ❑HELIX-Atlanta Respiratory Health Team

- ❑ **RH Team Pilot Data Linkage Project:**
- ❑ **Link environmental data related to ground-level $PM_{2.5}$ (NASA+EPA)**
- ❑ **with health data related to asthma**

**Goals:**

1. **Produce and share information on methods useful for integrating and analyzing data on asthma and $PM_{2.5}$ for environmental public health surveillance.**
2. **Generate information and recommendations valuable to sustaining surveillance of asthma with $PM_{2.5}$ in the Metro-Atlanta area.**

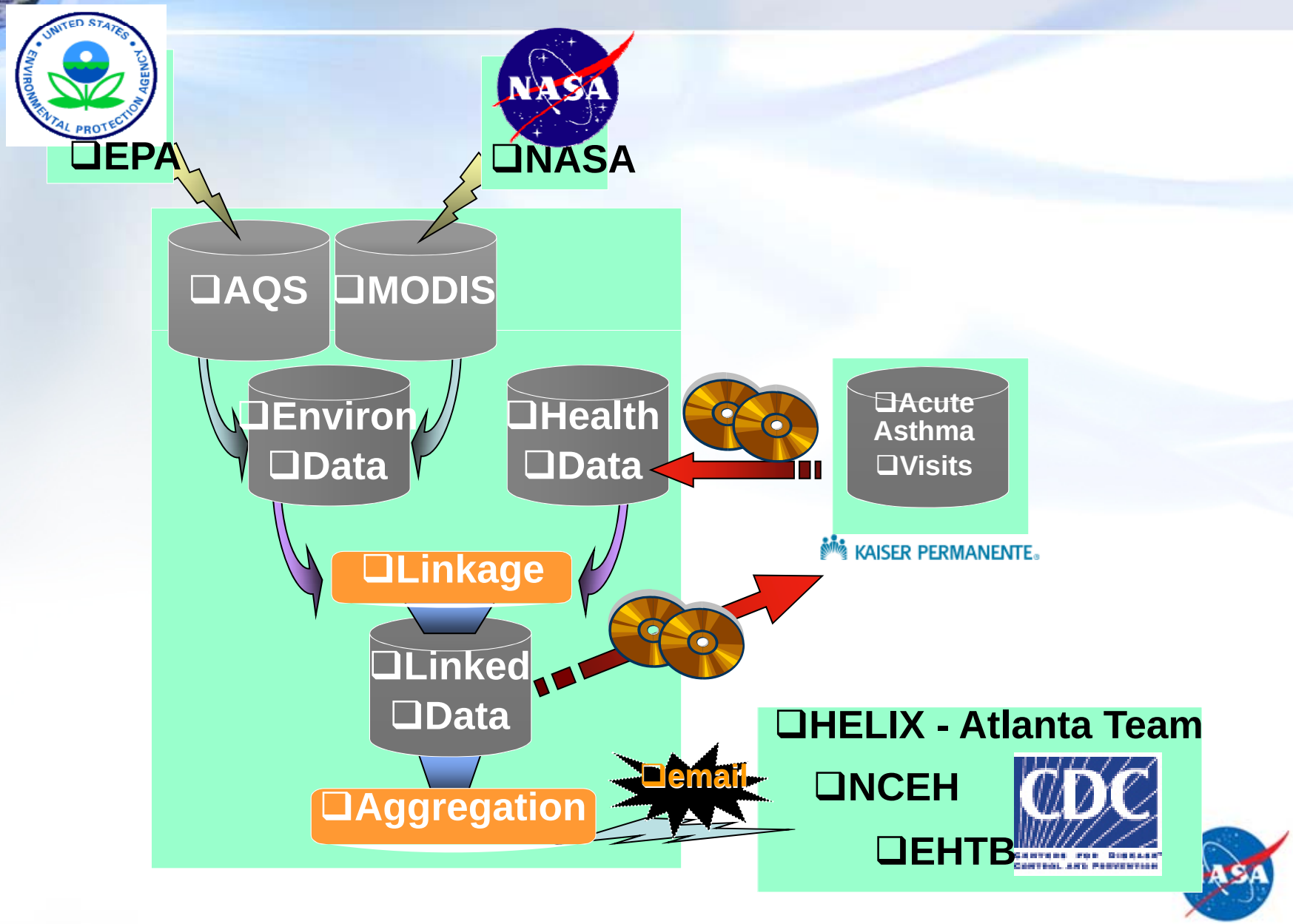
**Environmental Hazard Measure: Daily $PM_{2.5}$**

**Asthma Measure: Daily acute asthma office visits to KP-GA Medical Facilities**

**Time period: 2001-2003**

**Linkage Domain: 5-county metropolitan Atlanta**

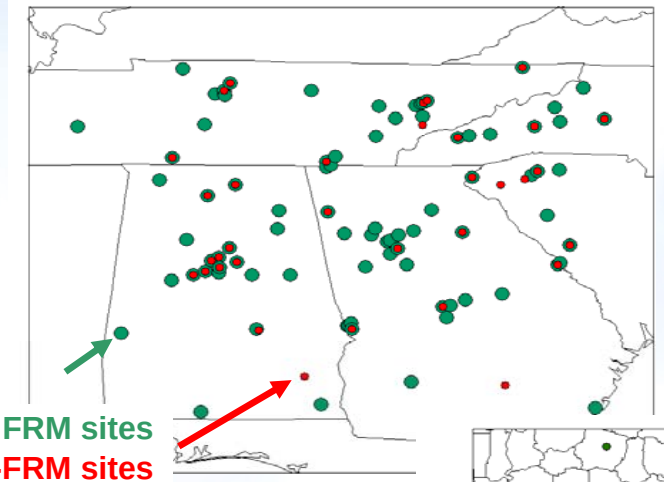
# ❑Data Linkage

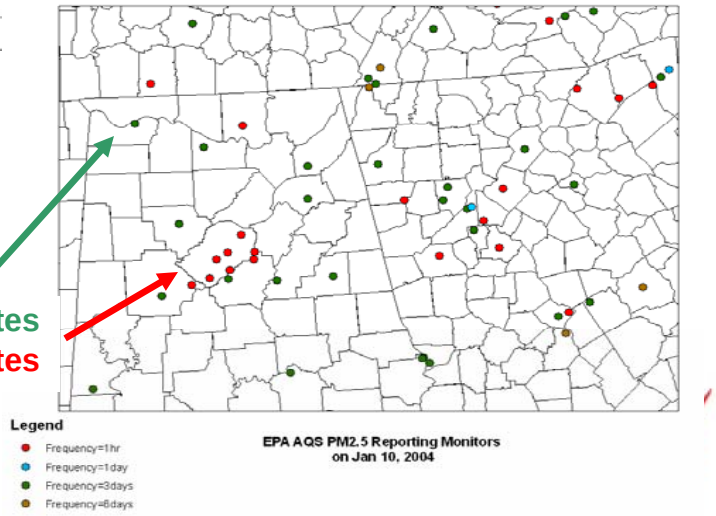


# ❑Sources of $PM_{2.5}$ data: EPA AQS

❑**EPA Air Quality System (AQS) ground measurements**

- ➢ National network of air pollution monitors
- ➢ Concentrated in urban areas, fewer monitors in rural areas
- ➢ Time intervals range from 1 hr to 6 days (daily meas. every 6th day)
- ➢ Three monitor types:
  - Federal Reference ❑Method (FRM)
  - Continuous
  - Speciation
- ➢ FRM is EPA-accepted standard method; processing time 4-6 weeks



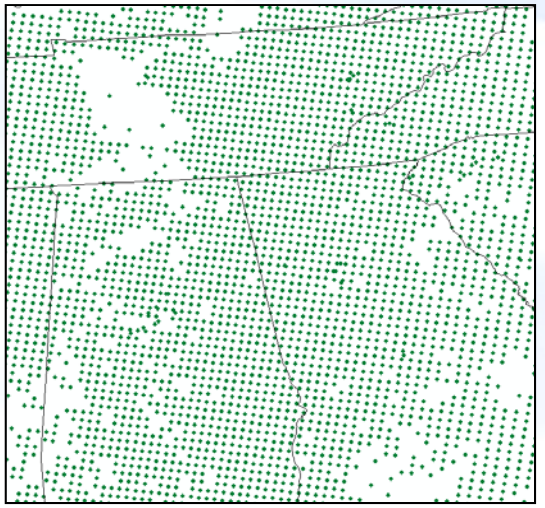
# ❑Sources of $PM_{2.5}$ data: MODIS

❑ **MODIS Aerosol Optical Depth (AOD)**

- **AOD is a measure of the total particulate in the atmosphere**
- **If atmosphere is well mixed, AOD is a good indicator of surface $PM_{2.5}$**
- **Enhanced Spatial Coverage**
- **Provided on a 10x10 km grid**
- **Available twice per day**

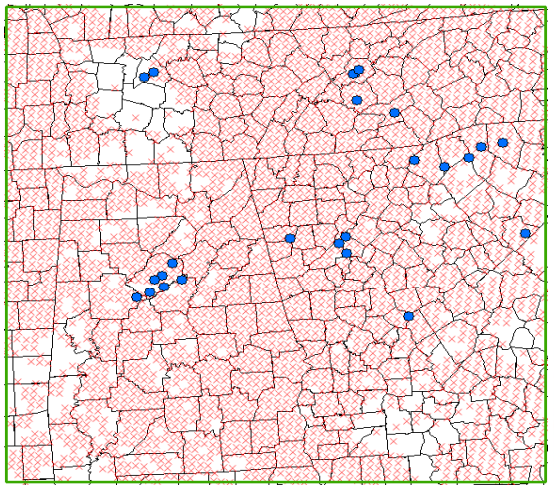
**(Terra ~10:30 AM, Aqua ~1:30 PM)**

- **Clear-sky coverage only**
- **Available since spring 2000**



❑MODIS

❑June 25, 2003

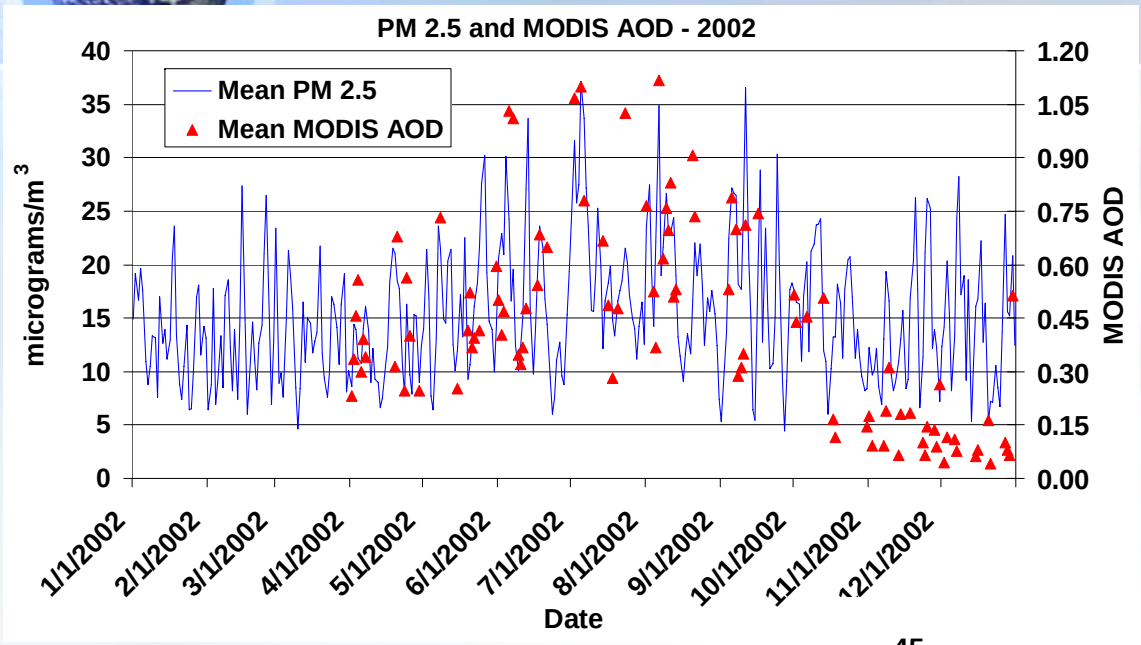


❑AQS

# ❑Estimating $PM_{2.5}$ from MODIS data

- For 2002-2003, obtain MODIS AOD and EPA AQS $PM_{2.5}$ data
- Extract AOD data for 5 AQS site locations
- Calculate daily averages from hourly AQS $PM_{2.5}$ data
- Using daily $PM_{2.5}$ averages from all 5 Atlanta AQS sites, determine statistical regression equations between $PM_{2.5}$ and MODIS AOD
- Apply regression equations to estimate $PM_{2.5}$ for each 10 km grid cell across region

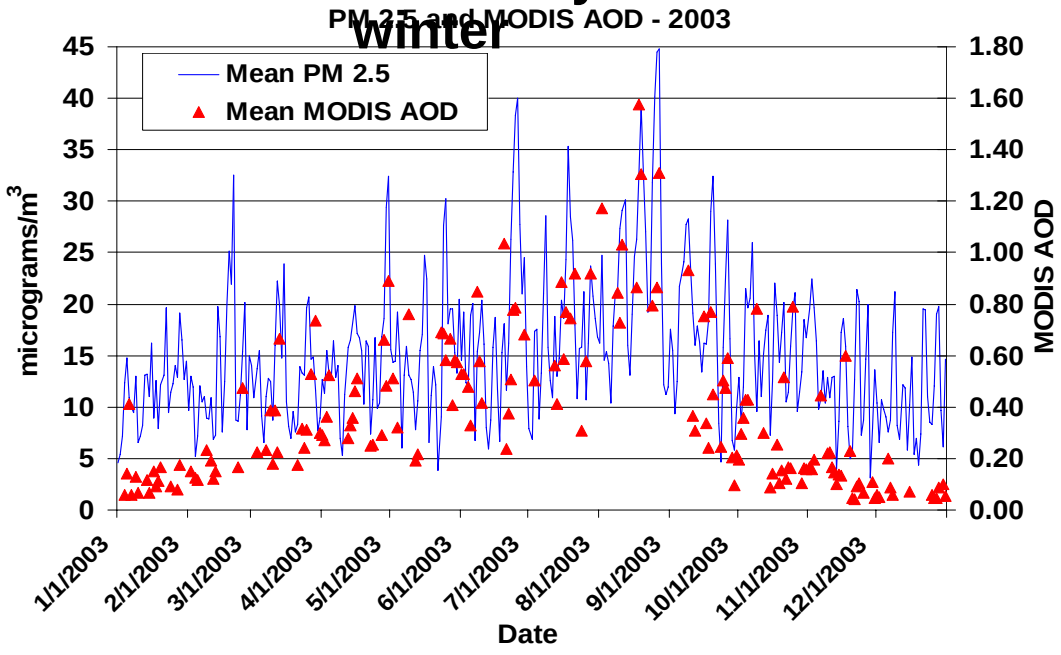
# ❑MODIS AOD - $PM_{2.5}$ Relationship




- Daily 5-site means of observed $PM_{2.5}$ and MODIS AOD
- MODIS data not available every day due to cloud cover
- MODIS AOD follows seasonal patterns of $PM_{2.5}$ but not the day-to-day variability in fall and winter

❑2002

❑2003



# ❑PM 2.5 – MODIS AOD Correlations

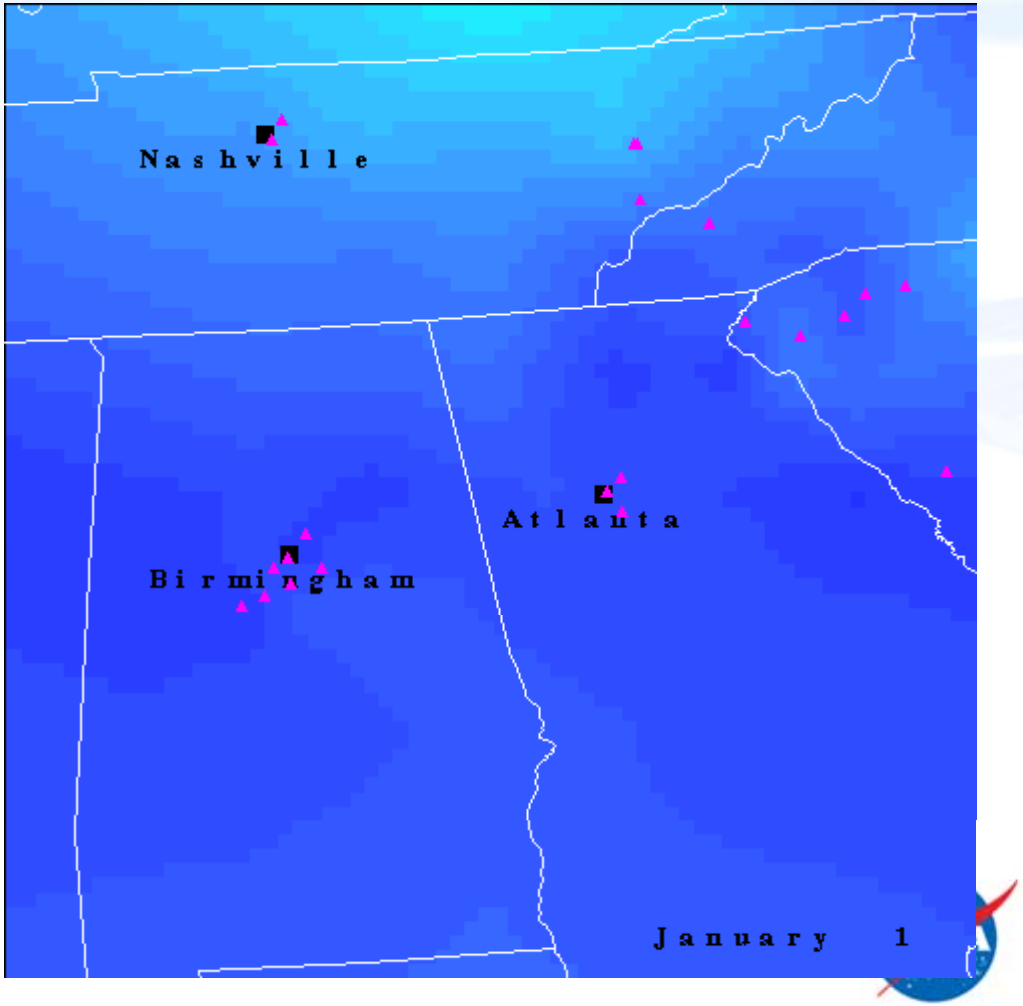
## ❑April - September

| | MODIS-Terra | MODIS-Aqua |
|---|---|---|
| 2000 --> | 0.579 | |
| 2001 --> | 0.643 | |
| 2002 --> | 0.559 | 0.401 |
| 2003 --> | 0.661 | 0.727 |

- Correlations between $PM_{2.5}$ and MODIS AOD are generally high (> 0.55) for the warm season.
- The lower correlation for MODIS-Aqua in 2002 is for July-September only.

# ❑PM2.5 Exposure Assessment- Spatial Surfacing

- 1st degree recursive B-spline in x- and y-directions
- Inverse Distance Weighted (IDW)
- Daily surfaces created on a 10x10 km grid
- Variable number of measurements available each day

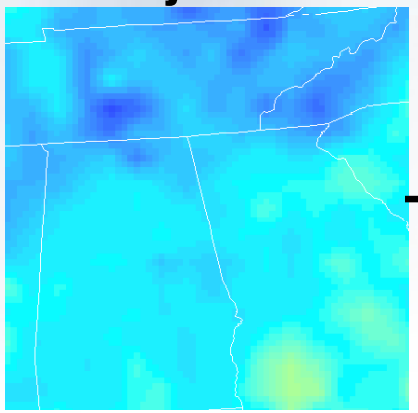


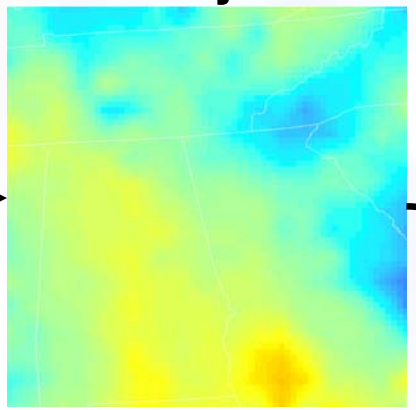
# ❑Merging MODIS and AQS $PM_{2.5}$ Data

- MODIS and AQS data have been merged to produce final $PM_{2.5}$ surfaces.

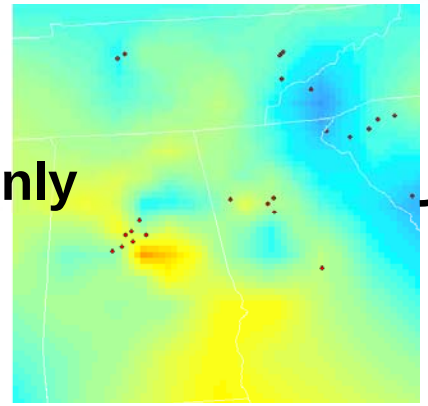
## ❑B-Spline Surfacing

❑Unadjusted MODIS ❑Bias-adjusted MODIS

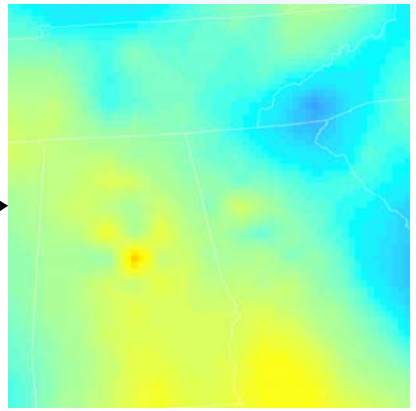




❑AQS only



❑Merged



❑65 μg/m

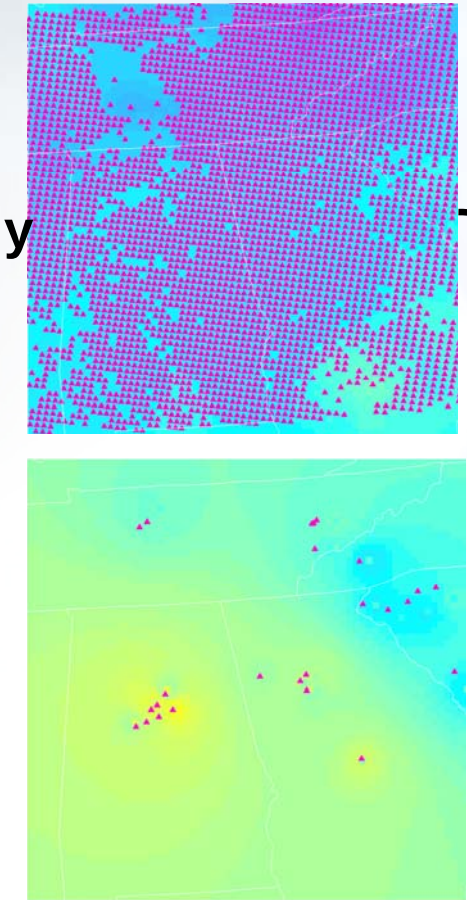
❑0 μg/m

# ❑Merging MODIS and AQS $PM_{2.5}$ Data

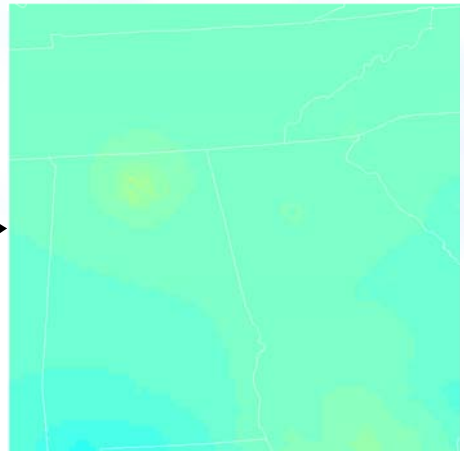
## ❑IDW Surfacing

❑MODIS Only

❑AQS only



❑Merged

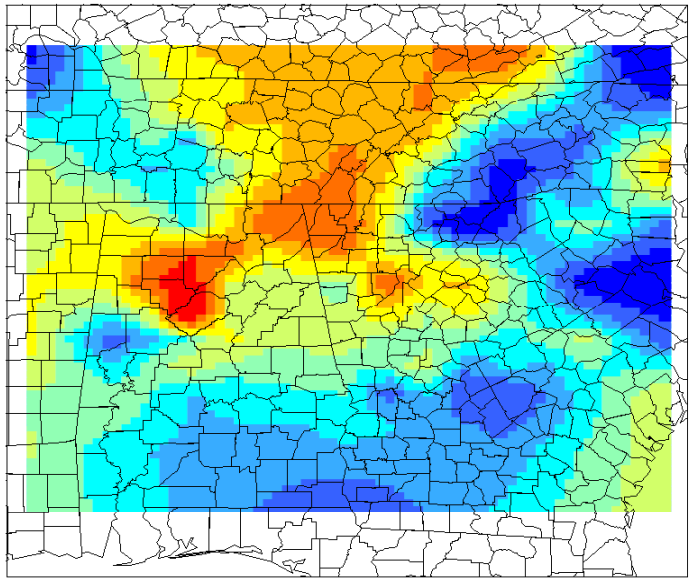


❑65 μg/

❑0 μg/m

# ❑Annual Composite Surfaces

PM2.5 B-Spline Surfaces Year 2003 Composite

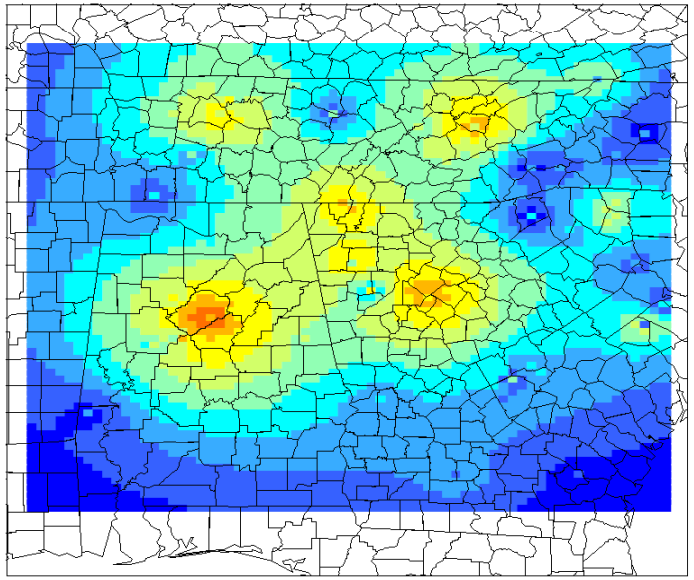


❑PM2.5 ($ug/m^3$)

- 11.98 - 12.57
- 12.58 - 12.97
- 12.98 - 13.35
- 13.36 - 13.74
- 13.75 - 14.23
- 14.24 - 14.85
- 14.86 - 15.54
- 15.55 - 16.50
- 16.51 - 18.36

❑B-Spline

PM2.5 IDW Surfaces Year 2003 Composite



❑PM2.5 ($ug/m^3$)

- 11.98 - 12.57
- 12.58 - 12.97
- 12.98 - 13.35
- 13.36 - 13.74
- 13.75 - 14.23
- 14.24 - 14.85
- 14.86 - 15.54
- 15.55 - 16.50
- 16.51 - 18.36

❑IDW

# ❑Linkage of Environmental and Health Data

## ❑Health Data Set

### ❑ Members

| ❑ LON | LATID | AGE | GENDER | YEAR/MO |
|---|---|---|---|---|
| ❑ -84.207 | 99.200 | 1 | ChildM | 200301 |
| ❑ -84.802 | 99.359 | 2 | AdultM | 200301 |
| ❑ -83.798 | 99.993 | 4 | ChildF | 200301 |

### ❑Acute asthma office visits

| ❑ID | AGE | LON | LAT | GENDER | DATE |
|---|---|---|---|---|---|
| ❑1811 | Child | -84.179 | 99.118 | F | 1/1/2003 |
| ❑54767 | Adult | -84.625 | 99.802 | F | 1/1/2003 |
| ❑84580 | Adult | -84.679 | 99.691 | F | 1/1/2003 |

❑*Simulated Data Set. F=female, M=male, A=adult, C=child.

# ❑Linkage of Environmental and Health Data

## ❑Data Linkage Outputs

### ❑Visit counts by grid cell

| ❑ Date | Cell | PM2.5 | FC | MC | FA | MA |
|---|---|---|---|---|---|---|
| ❑200301 | 1 | 21.74 | 1 | 0 | 2 | 0 |
| ❑200301 | 2 | 12.79 | 0 | 0 | 0 | 0 |
| ❑200301 | 3 | 12.21 | 0 | 1 | 0 | 1 |

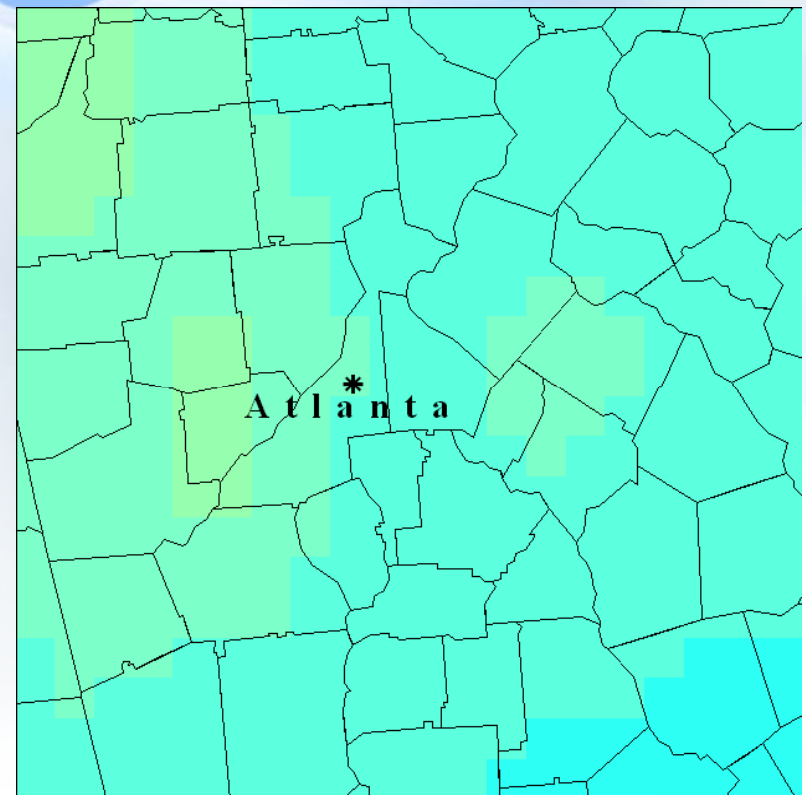
### ❑$PM_{2.5}$ for each visit

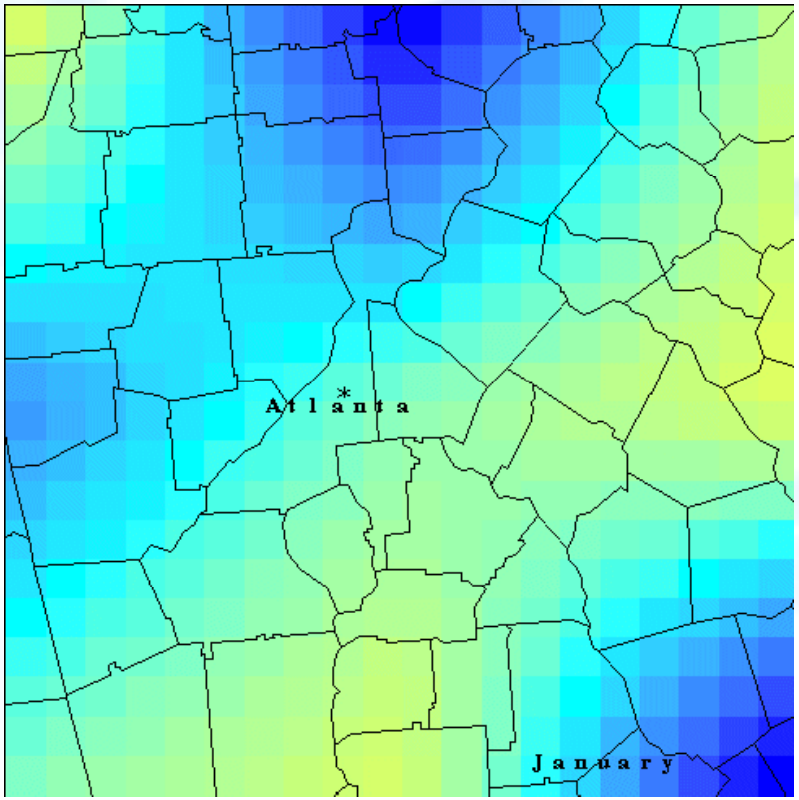
| ate | ID | Member Lat/Lon | Cell | Cell Lat/Lon | County | State | Gender | Age | P |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1811 | 99.572 -84.251 | 1944 | 99.552 -84.284 | Coweta | GA | F | Child | 2 |
| 2 | 15299 | 99.063 -83.860 | 1608 | 99.104 -83.806 | Upson | GA | F | Child | 1 |
| 2 | 15879 | 99.727 -84.369 | 2079 | 99.731 -84.403 | Fulton | GA | M | Child | 1 |

❑*Simulated Data Set. F=female, M=male, A=adult, C=child.

# ❑Linkage of Environmental and Health Data

❑Year
2002




❑ Monthly Mean $PM_{2.5}$ ($ug/m^3$)

❑3
0

❑0

January

❑Monthly Asthma Visits Rate (Per 10,000)

❑8
0

❑0

❑Year
2002

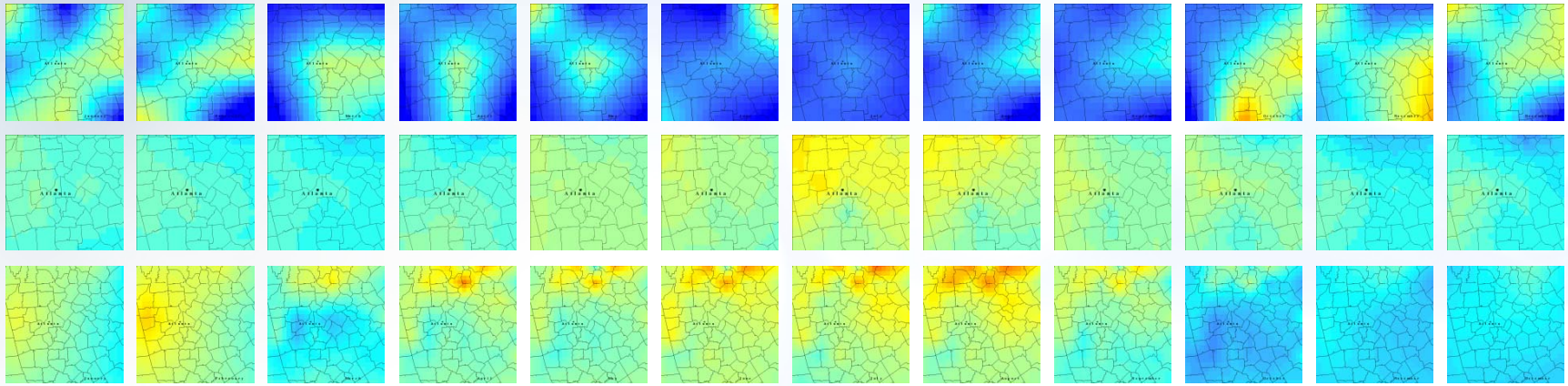
# ❑Linkage of Environmental and Health Data

❑Jan. ❑Feb. ❑Mar. ❑Apr. ❑May ❑Jun. ❑Jul. ❑Aug. ❑Sep. ❑Oct. ❑Nov. ❑Dec.

❑Rates

❑PM2.5

❑Ozone

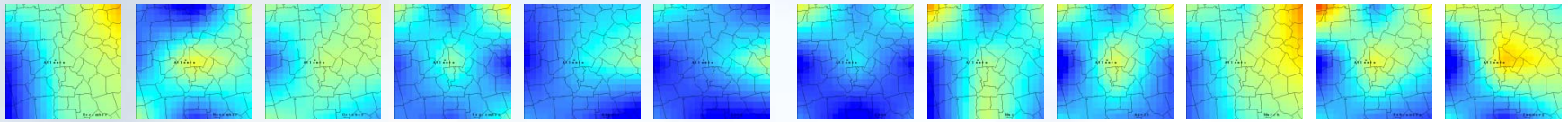


❑Year 2002

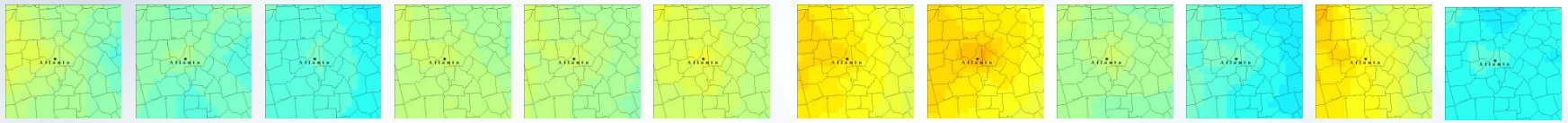
# ❑Linkage of Environmental and Health Data

❑Jan. ❑Feb. ❑Mar. ❑Apr. ❑May ❑Jun. ❑Jul. ❑Aug. ❑Sep. ❑Oct. ❑Nov. ❑Dec.

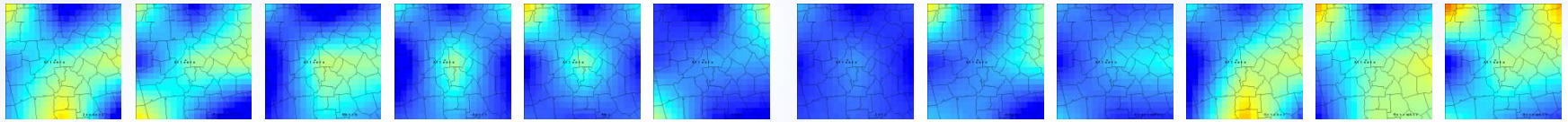
❑Rates ❑2001



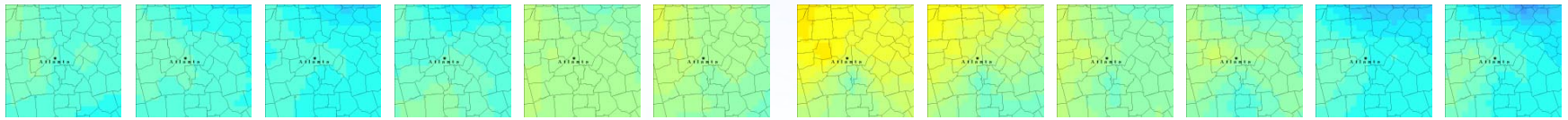
❑PM2.5 ❑2001



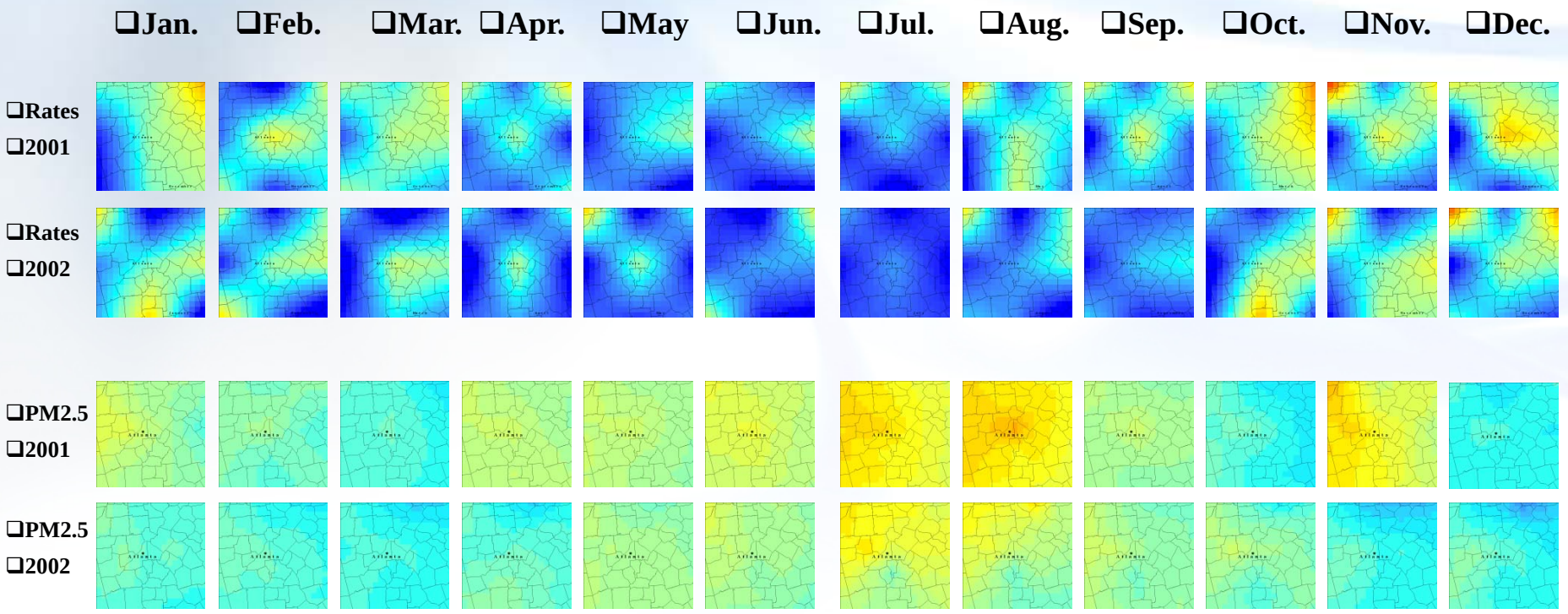
❑Rates ❑2002



❑PM2.5 ❑2002



# ❑Linkage of Environmental and Health Data



# ❑Successes

- **Proven the feasibility of linking environmental data (MODIS $PM_{2.5}$ estimates and AQS) with health data (asthma)**
- **Developed algorithms for QC, bias removal, merging MODIS and AQS $PM_{2.5}$ data, and others…**
- **Developed spatial maps of exposure rates to $PM_{2.5}$ based on MODIS and AQS data**
- **Negotiated a Business Associate Agreement with a health care provider to enable sharing of Protected Health Information**

# ❑Team Members and Acknowledgements

## ❑ Member's Name, Affiliation

- John Haynes, Program Manager, Public Health, NASA Headquarters
- (*Co-Chair)* Kafayat Adeniyi, Centers for Disease Control and Prevention,
- (*Co-Chair)* Solomon Pollard, Environmental Protection Agency (EPA), Region 4
- Mohammad Z. Al-Hamdan, Universities Space Research Association/NSSTC
- Rob Blake, DeKalb County Board of Health
- David Blaney, Georgia Division of Public Health
- Bill Crosson, Universities Space Research Association/NSSTC
- Maury Estes, Universities Space Research Association/NSSTC
- Kristen Mertz, Georgia Division of Public Health
- Amanda Sue Niskar, Centers for Disease Control and Prevention
- Dale Quattrochi, National Aeronautics and Space Administration
- Amber Sinclair, Kaiser Permanente
- Allison Stock, Centers for Disease Control and Prevention
- Denis Tolsma, Kaiser Permanente
- Linda Thomas, Environmental Protection Agency, Region 4
- Ntale Kajumba, Environmental Protection Agency, Region 4
- Carolyn Williams, Georgia Division of Public Health

## ❑ Acknowledgments


- Leslie Fierro, Centers for Disease Control and Prevention
- Gabriel Rainisch, Centers for Disease Control and Prevention
- Emily Hansen
- HELIX-Atlanta Partners

# ❑Continued Work

❑Proposal Submitted to ROSES ‘08

❑“Decision Support through Earth Science Research Results” (A18)

❑in Conjunction with the CDC and others

- ❑***“Enhancing Environmental Public Health Tracking with***
- ❑ ***Satellite-Driven Particle Exposure Modeling and Epidemiology”***

- ❑**Dr. Yang Liu, PI. Harvard University School of Public Health**
- ❑**Co-I’s from the Centers for Disease Control and Prevention**

- www.cdc.gov/nceh/tracking